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The Journal of HEREDITY

ARE THEY IDENTICAL?

The Rex Rabbit

A Bud Selection in Pears

Artificial Culture of Plant Embryos

Order of Birth of Mental Deficients

"High-Brow" Rats

Lightning Calculators and Heredity

VOLUME 20 MAY, 1929 NUMBER 5

The American Genetic Association

An incorporated organization devoted to promoting a knowledge of the laws of heredity and their application to the improvement of plants, animals, and human racial stocks

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The

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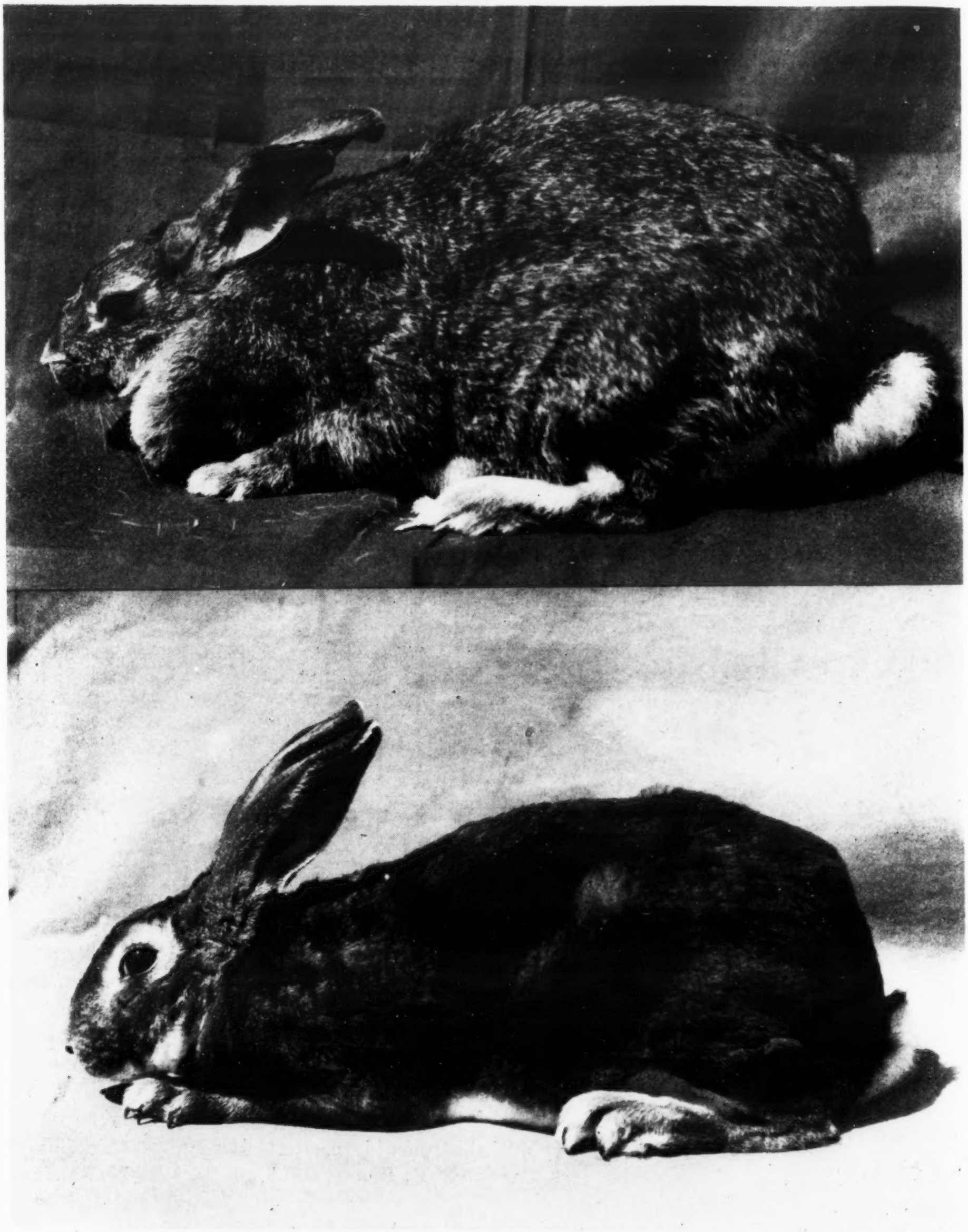


A CARRIER OF THE REX FACTOR AND A GRAY REX RABBIT

Frontispiece

Above—A gray rabbit with normal coat. This animal was sired by a castorrex rabbit, and was heterozygous for the rex character, though it did not show it. This was one of the original animals received from Berlin in April, 1926, and was ancestor to some of the rex animals shown in other figures.

Below—A gray Rex or "Castorrex" rabbit, which gives an idea of the change made in the coat by the rex gene when present in a homozygous state. Rex rabbits produce only rex offspring when bred with each other.

THE REX RABBIT

W. E. Castle

Bussey Institution, Harvard University, Forest Hills, Boston, Mass.

STUDIES of heredity in the domestic animals made in the last 25 years show that the different varieties and breeds of any single species differ from each other chiefly in a rather small number of unit-characters which occur in different breeds in different combinations.

Each unit-character difference can be referred to the action of alternative states of a single gene borne in a particular chromosome of the germ-cell. It is assumed that each gene had a single original state or form; and that alternative states have arisen by a mutation or change from this original state, and that these mutations having once arisen have a strong tendency to persist.

The time and place of the origin of gene mutations in our domestic animals are largely unknown. Many of the breed differences are known to have existed for centuries and it is now impossible to discover where or when they first appeared.

It is of interest, therefore, to record the contemporary appearance of gene mutations and their synthesis into breeds, as giving strong support to the mutation theory.

I have elsewhere described such an origin in the present century for two yellow varieties of the common rat (*Mus norvegicus*) and Crew has described the occurrence of a similar mutation in *Mus rattus*. A chocolate mutation in the domestic rabbit first came to notice in Holland about 1900 and is now familiar throughout Europe and America as the Havana rabbit. It is the purpose of this note to discuss a still more recent mutation of the rabbit which appeared in France about five years ago and is now widely known among rabbit breeders. This is found in the so-called rex rabbit which differs from ordinary breeds in the length and texture of the fur.

Ordinary rabbit fur contains long, coarse "guard" hairs interspersed with more numerous shorter and softer "wool" hairs which constitute the warm underfur. In making up rabbit skins into fur garments, the guard hairs are commonly "plucked" out, a tedious and laborious process.

Now the rex rabbit has no guard hairs, or rather they are so little different from the other hairs in the rex coat that plucking is unnecessary. The entire coat is made up of short, soft, plush-like hairs and the rex breeds give promise of being valuable to the furrier.

"Rex" a Recessive Character

The character is inherited as a simple Mendelian recessive. I have had an opportunity in the past two years to study the behavior of this character in crosses, through the kindness of Dr. Hans Nachtsheim of the Institut für Vererbungsforschung, Berlin, Germany. When coming to America in the spring of 1926, he generously brought to me from Berlin two pairs of rabbits sired by a rex individual. They are ordinary gray rabbits in appearance, their mothers having been normal coated albino or chinchilla rabbits. But the rex character made its appearance in one-fourth of their young as expected when they were mated *inter se*, and the rex individuals among themselves produce only rex young in typical recessive Mendelian fashion.

So much was known when I began working with the variety. With the kind coöperation of Dr. Nachtsheim I set myself the task of finding out what were the linkage relations of this newly discovered gene to genes of the rabbit previously known.

Nine such genes were at that time known and two others have since been

discovered. These genes and their linkage relations thus far demonstrated are shown in Table I.

Gene No. 12 is responsible, in a recessive mutation, for the "naked" (practically hairless) condition described by A. D. Kislovsky as occuring in a rabbit colony in Russia.* Its linkage relations have not been studied so that it can not at present be referred to any particular chromosome.

The linkage relations of the gene for rex have been studied with reference to all genes except naked (12) and brown (2). The last case is now being studied but is confidently expected to prove negative, since rex has been found to give free assortment in relation to both 3 and 4, which are in the same linkage system designated chromosome II in Table I.

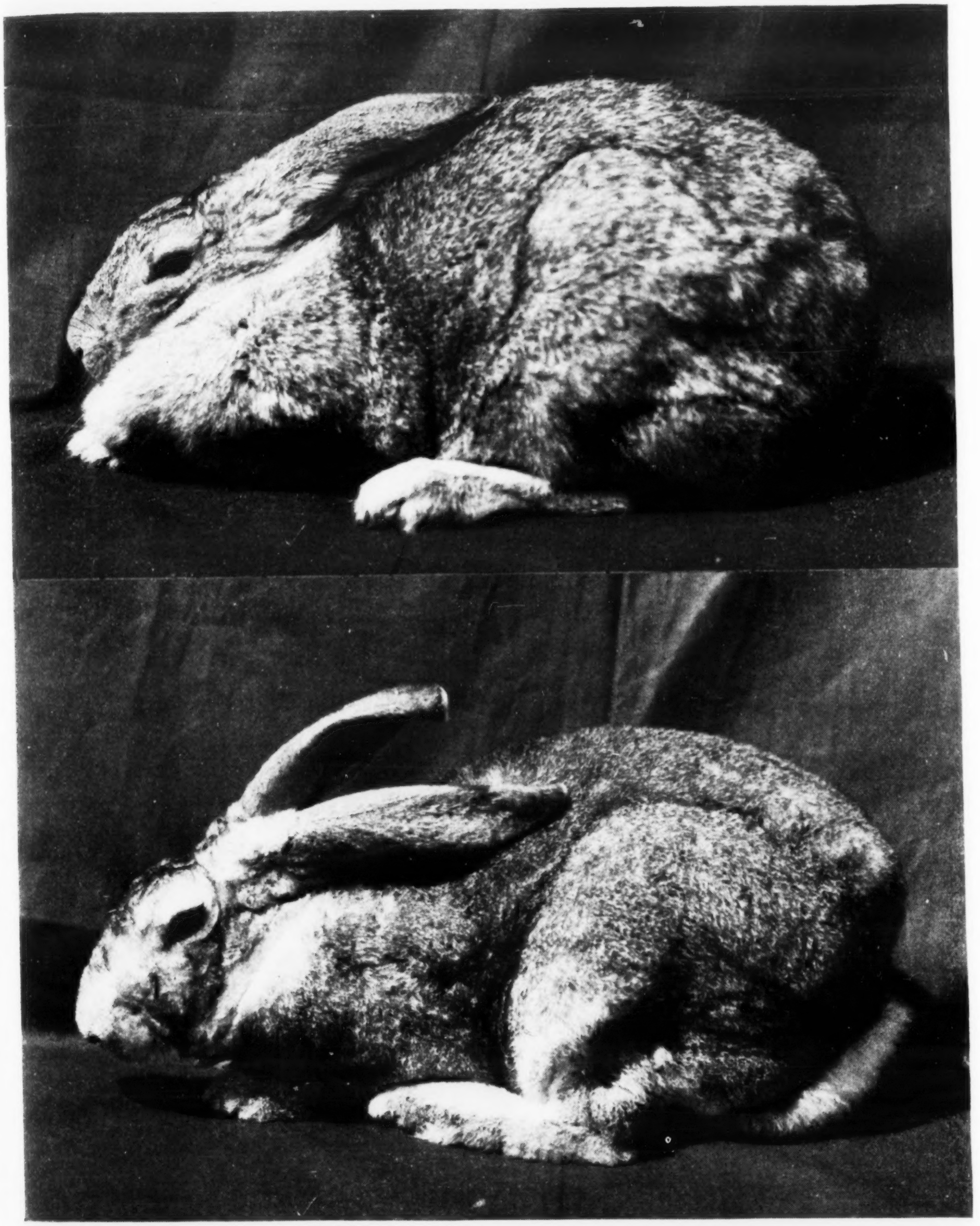
The linkage tests have been made by the back-cross method of crossing an F_1 individual with a double recessive. As rex is a recessive mutation, like all but one of the other mutations of the rabbit, the method involved first the production of F_1 individuals heterozygous for rex as well as the other character to be studied. Next an F_2 population had to be produced to obtain the double recessive combination, since in all but two crosses the characters entered the F_1 in the repulsion relation, that is from different parents. Then the desired back-cross between F_1 and a double recessive could be undertaken.

Only in the case of gene No. 7, English, and gene No. 4, yellow fat, was it unnecessary to raise an F_2 generation. English is a dominant and any non-English rex individual represents the double recessive combination used in the back-cross to test for linkage. Yellow fat was introduced into F_1 in the

TABLE I—Genes of the Domestic Rabbit and Their Chromosome Relations

Chromosome	Gene	Allelomorphs	Symbols
I	1	Agouti vs. black-and-tan vs. non-agouti	A, a^t, a
II	2	Black vs. brown	B, b
	3	Full color vs. chinchilla vs. Himalayan vs. complete albino	C, c^{ch}, c^H, c
	4	White fat vs. yellow fat	Y, y
III	5	Intense vs. dilute color	D, d
IV	6	Extended vs. dark extended vs. Japanese vs. restricted black or brown (restricted phenotypically yellow)..	E, E^D, e^J, e
V	7	English spotted vs. unspotted (self)coat	En, en
	8	Self vs. Dutch spotted coat ...	Du, du
	9	Ordinary short vs. long (Angora) coat	L, l
VI	10	Ordinary short vs. rex coat ...	R, r
VII	11	Self colored vs. Vienna white (blue-eyed white)	V, v
?	12	Normal coat vs. naked (hairless)	N, n

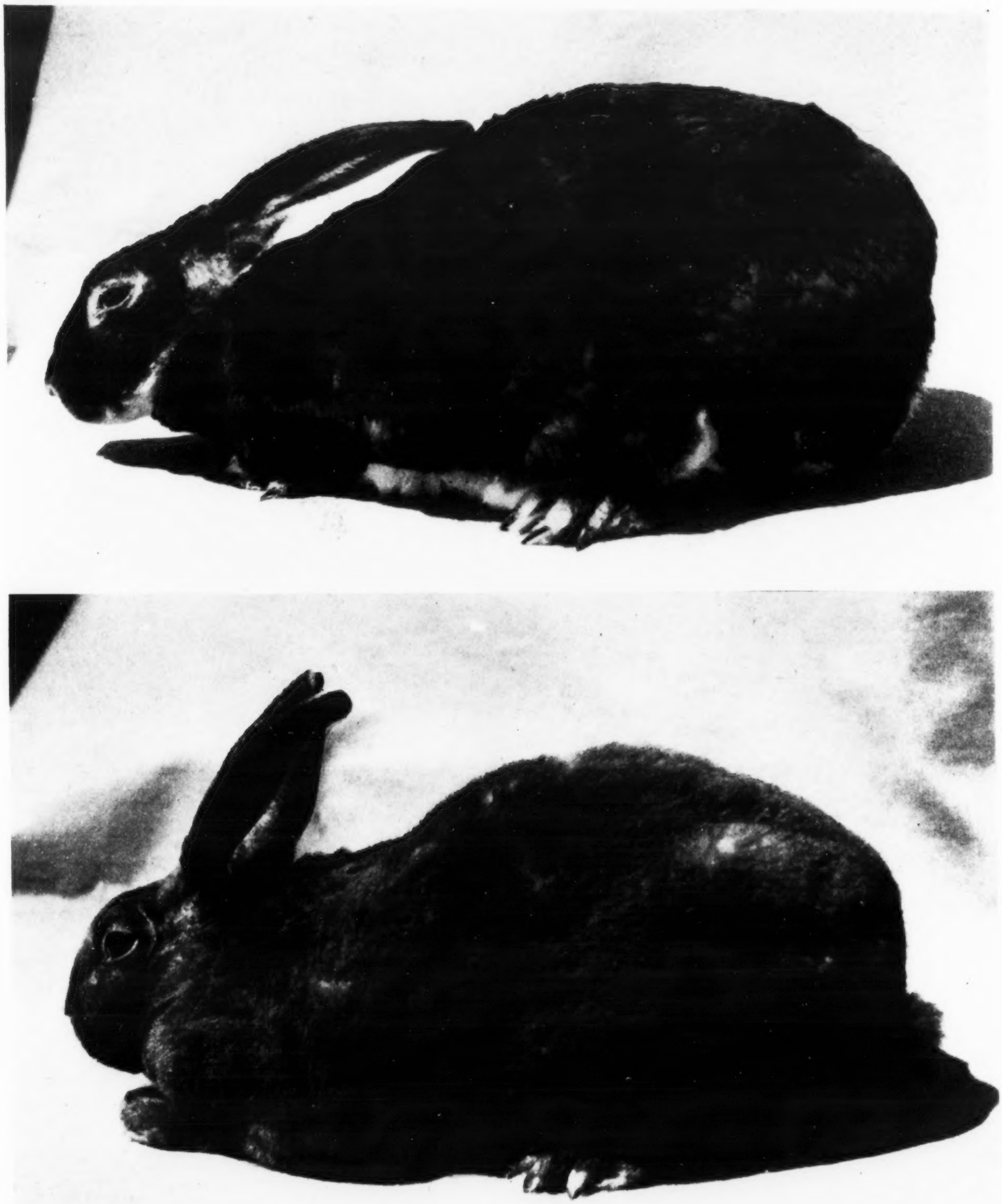
Jour. Heredity 19:438. 1928.



NORMAL CHINCILLA AND CHINCILLA REX RABBITS

Figure 1

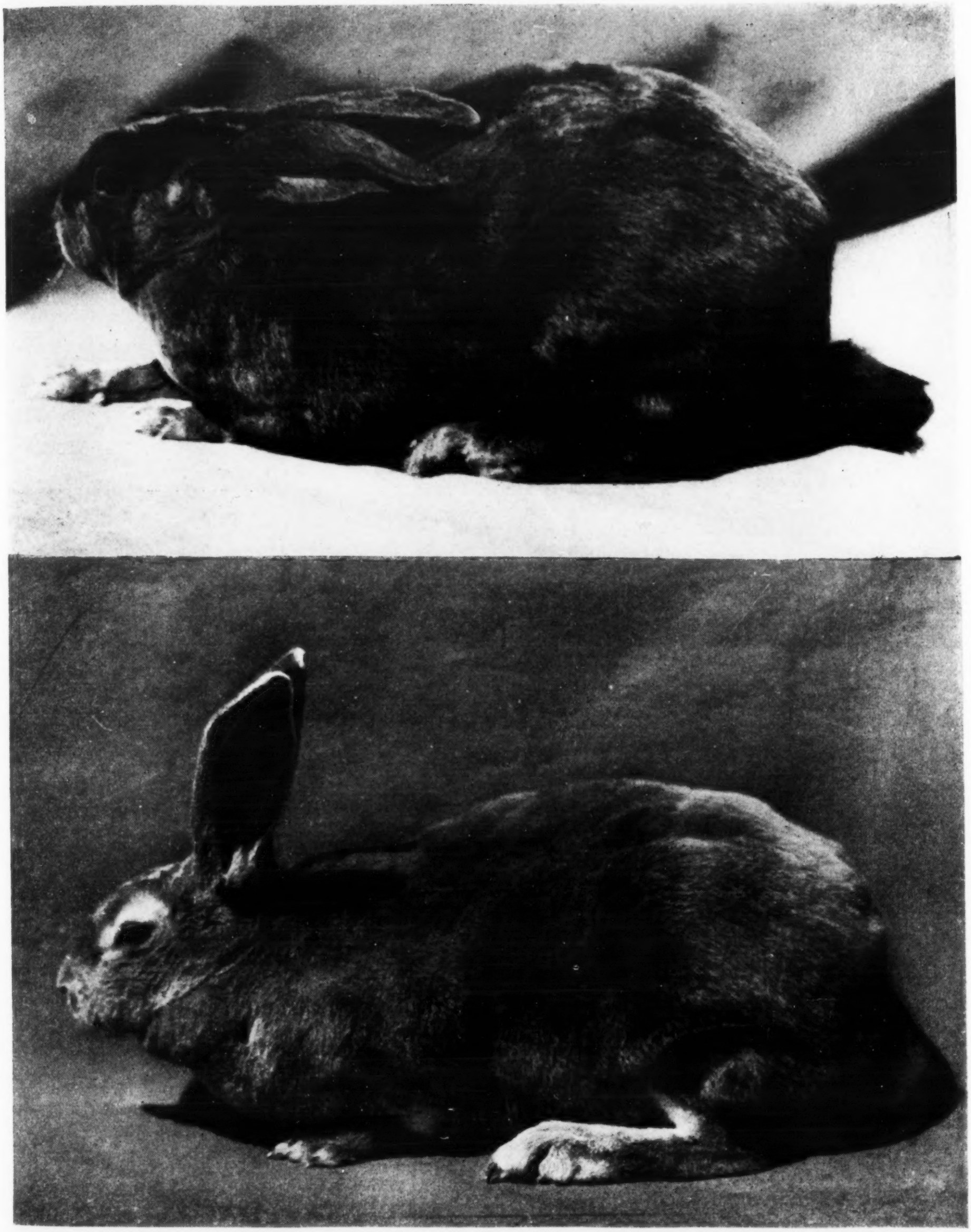
Note difference in texture of fur including the "whiskers" or vibrissæ, which are shorter, smaller, and less straight in the presence of the homozygous rex factor. This character allows one to distinguish the rex individuals in mixed litters at birth, before the body hairs are developed.



PLUSH-LIKE FUR OF THE "REX"

Figure 2

A black-and-tan rex rabbit (above) which shows the remarkable plush-like character of the fur in selected specimens. This animal was moulting when the picture was taken, so that the condition of the fur was not "prime." Below is shown a non-agouti or sooty yellow (known also as "tortoise shell") rex rabbit.



TWO BEAUTIFUL REX COLOR COMBINATIONS

Figure 3

The blue rex (above) is one of the most promising of the color-rex combinations. The dilute Black-and-Tan Yellow Rex (below) is one of the most beautiful combinations yet obtained and easy to "fix" in a true breeding type since it contains so many recessive genes.

The rex character is not linked with any of the color genes, so a great variety of color combinations with rex can be obtained.

same gamete with rex, so a back-cross of F_1 with a rex individual having yellow fat furnished the desired linkage test.

The original animals brought to me by Dr. Nachtsheim were F_1 animals from a cross of rex with two different mutants of gene No. 3. One pair had been produced by a cross between rex and chinchilla, the other pair by a cross between rex and complete albinism. As chinchilla and albinism are allelomorphs, they could be used interchangably in tests for linkage with rex. The first litter of F_2 young obtained from these parents contained one of the desired double recessive individuals, a chinchilla rex. Others were obtained in later litters and within a few months the back-cross matings were begun.

It was a slower process to obtain some of the other double recessive combinations. The original F_1 males were for this purpose crossed with various races of rabbits containing one or another of the characters whose relation to rex was to be tested. It was expected that the F_1 parent would transmit rex to only half of his offspring, since he was heterozygous for rex. Those offspring which had received the rex gene had to be identified by test matings among themselves, or with their sire, or with a homozygous rex individual, several of which had by this time been produced. Any individual which produced one or more rex young in any of these types of matings was by that fact proved to be heterozygous for rex. In this way double heterozygotes for rex and each of the other genes listed in Table I except 2 and 12 were identified within a few months, and in due time double recessives were produced by them and the back-crosses made.

The promptness with which double recessives were produced indicated the probability that no linkage existed between rex and any of the other known genes. This conclusion has been confirmed by the results of the back-crosses which are summarized in Table II. In explanation of that table it may be said that the four classes of phenotypes produced by each back-cross are expected to be equal in case no linkage exists. Rex classes are designated by *b*. Accordingly the *Ab* and *ab* columns show the numbers of rex offspring obtained, whereas columns *AB* and *aB* include the non-rex young. Crossover classes, *i. e.* combinations unlike those found in the parents of the F_1 individuals are indicated by a *.

An examination of Table II shows that in four of the back-crosses crossovers are in excess of non-crossovers, *i. e.* exceed 50 per cent, which of course is demonstrative proof that no linkage exists in those cases. In the three remaining cases, the cross-over percentage is les than 50, but the departure from 50 is not statistically significant since in the most extreme case, that of English and rex, it is only 2.4 times the probable error, and so may well be a result of random sampling.

A strong probability therefore exists that the gene for rex lies in a different chromosome from those which contain the other known genes of the rabbit, with the possible exception of No. 12, naked, whose linkage relations have not been studied.

Linkage Relations of Yellow Fat

A word may be said about the newly discovered character yellow fat first observed by Pease (1928)* and shown by him to be a simple recessive character in all probability strongly linked with gene No. 3 of Table I, since he observed it only in fully colored individuals, never in albinos, even in the F_2 of a cross with an albino race, Polish. Pease discovered the character in a race of Flemish Giants and I too have found it to occur in my race of Flemish Giants. Since it failed to appear in F_2 albinos obtained by Pease when the Flemish Giants having yellow fat were crossed with Polish, he was in doubt whether the correlation oc-

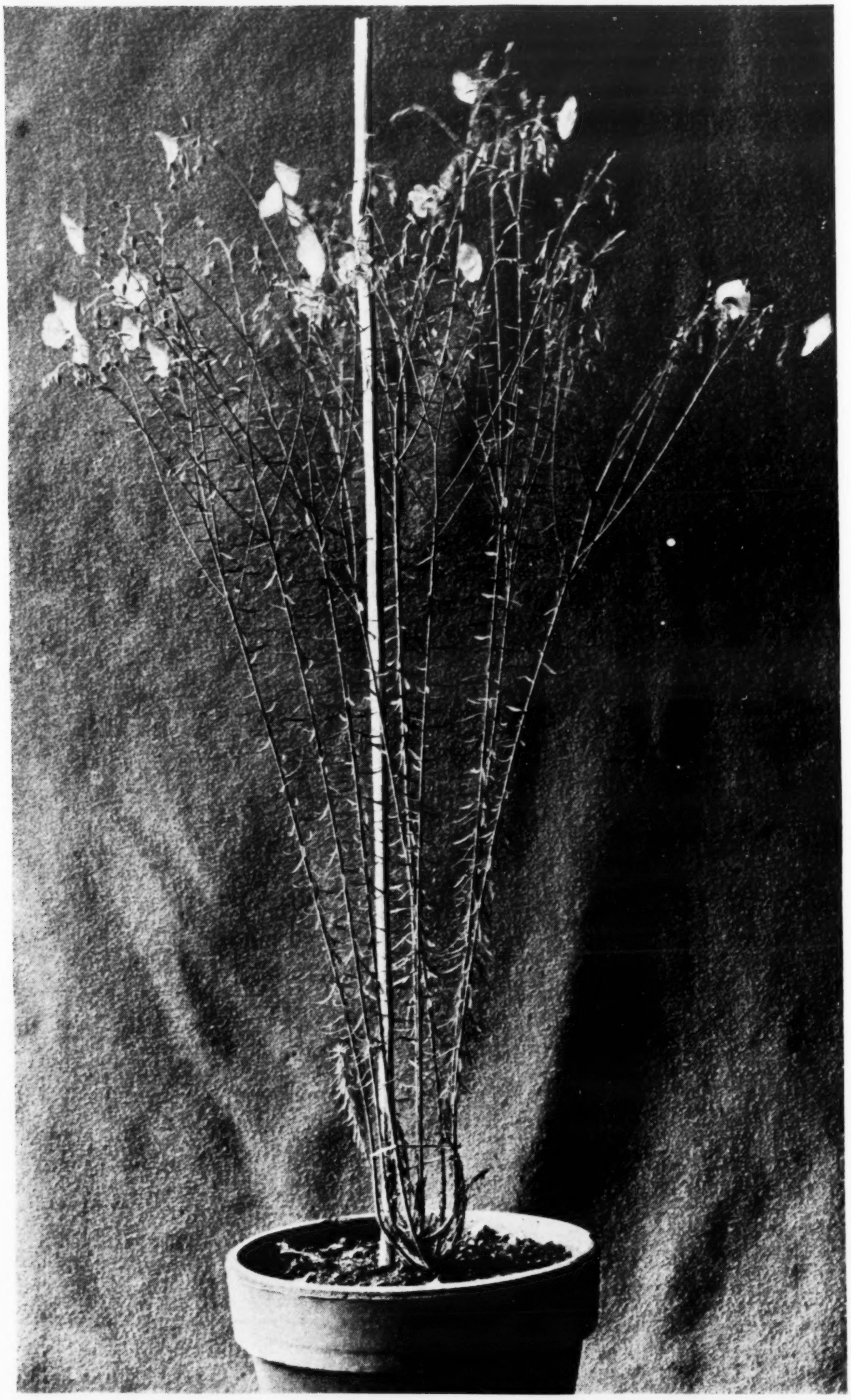
**Verh. V Internat. Kongresses f. Vererb.* Berlin, 1927.

curred for physiological or for genetic reasons, though he favored the latter view. This is shown to be correct by my own observations. I found yellow fat to occur among the chinchillas and albino rabbits extracted from rex crosses; and in two back-cross litters it occurred exclusively in chinchilla or albino segregates, never in the fully colored young. The 13 young of these two back-cross litters, which were reared to an age when the fat character could be determined, were produced by a triply heterozygous gray male, *CcRrYy*, mated with his triple recessive daughter, a yellow fat chinchilla rex, $c^{ch}crryy$, heterozygous for albinism. In other words, she bore two different recessive allelomorphs of the color factor, c^{ch} and c. In combination with the c gametes of her mate (and sire) zygotes would be produced either $c^{ch}c$ or cc in character, the former beinging chinchillas, the latter albinos. Among the 13 back cross young four were chinchillas and five albinos, *but all had yellow fat*, whereas the four fully colored young (Cc^{ch} or Cc in composition) had white fat. Now the gametes of the yellow fat mother must *all* have transmitted yellow fat. It is obvious, therefore, that the nine functional c sperms of the sire all carried yellow fat, since the progency had yellow fat also, whereas the four functional C sperms carried white fat. In this case we have linkage of albinism with yellow fat, and no cross-overs in 13 young. This is complementary to the observation of Pease, who observed linkage of yellow fat with full color, C, and no crossing-over in an F_2 population. It confirms his provisional conclusion that there is close linkage between genes 3 and 4 of Table I. His observations showed repulsion and mine show coupling between yellow-fat and albinism.

POSTSCRIPT—Since the foregoing was written two cross-overs between the genes for yellow fat and albinism have been observed in a total of about 40 back-cross young, indicating a cross-over percentage of about 5, or a linkage strength of about 90 on a scale of 100.—*W. E. C.*

TABLE II—Back-cross Tests for Linkage Between Rex and Other Genes of the Rabbit

	Phenotypes AB	Ab	aB	ab	Total	Cross-overs	Percent and P. E.
F_1 x non-agouti (aarr)	20*	24	0	26*	90	46	51.1 ± 3.5
F_1 x chinchilla rex ($c^{ch}c^{ch}$rr)	14*	11	22	13*	60	27	45.0 ± 4.3
F_1 x rex with yellow fat (rryy)	1	3*	5*	4	13	8	61.5 ± 9.3
F_1 x dilute rex (ddrr)	14*	10	8	11*	43	25	58.1 ± 5.1
F_1 x yellow rex (eerr)	44*	44	36	40*	164	84	51.2 ± 2.6
F_1 x non-English rex (en en rr)	67	50*	30*	68	245	110	44.8 ± 2.1
F_1 x Vienna white rex (vvrr)	12*	8	17	11*	48	23	47.9 ± 4.8



A HYBRID BROUGHT TO MATURITY BY ARTIFICIAL NUTRITION

Figure 4

When *Linum austriacum* is crossed with *L. perenne,* viable seeds are not produced. If the embryos are removed from the seed they can be nourished in a suitable medium and in this way the hybrid may be successfully raised, as in this instance. It is thus demonstrated that the hybrid is itself capable of development, but that it cannot develop in contact with the tissues of the parent species. The hybrids are inter-fertile and produce good seed in crosses with either parent species.—(See Figure 12.)

ECTOGENESIS IN PLANTS

Methods and Genetic Possibilities of Propagating Embryos Otherwise Dying in the Seed

F. LAIBACH

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LETHALITY in the animal and vegetable kingdoms has received greater attention since the researches of Morgan and his colleagues, on Drosophila, have emphasized the importance of lethal factors. In recent years a great number of cases of lethality genetically conditioned are said to have been found, not only in animals, but also in plants. In the following pages the author hopes to show that this notion has been extended too far, at least in plants, not because it was given to appearances of deficiency which set in only in later phases of ontogenetic development or which do not result in death (these cases are called sublethal) but because there are included cases where these inhibitions of development set in only under special conditions. I cannot agree with those who cite as examples of sublethality certain strains of *Mirabilis jalapa*, which are more sensitive to cold than the normal kindred, and which die at 4.7-7.8°C. Neither can we consider as sublethal the factors that diminish the capacity of corn to resist winter temperatures. It would also be untenable to describe as sublethal a hybrid that I obtained between *Linum hirsutum* and *L. viscosum*, which shows chlorophyll deficiencies in winter, the leaves becoming white, while it develops normally in summer, and even better than its parents. Where would such reasoning lead us? Then all the plants of warmer climates which are more sensitive to cold than the native plants would have to be called sublethal in comparison with the plants of the temperate zones. Then, the more a plant is adapted to fixed conditions of life, like a strictly specified parasite to its host, the more we must suppose greater sublethality in this plant compared with its less closely adapted relatives.

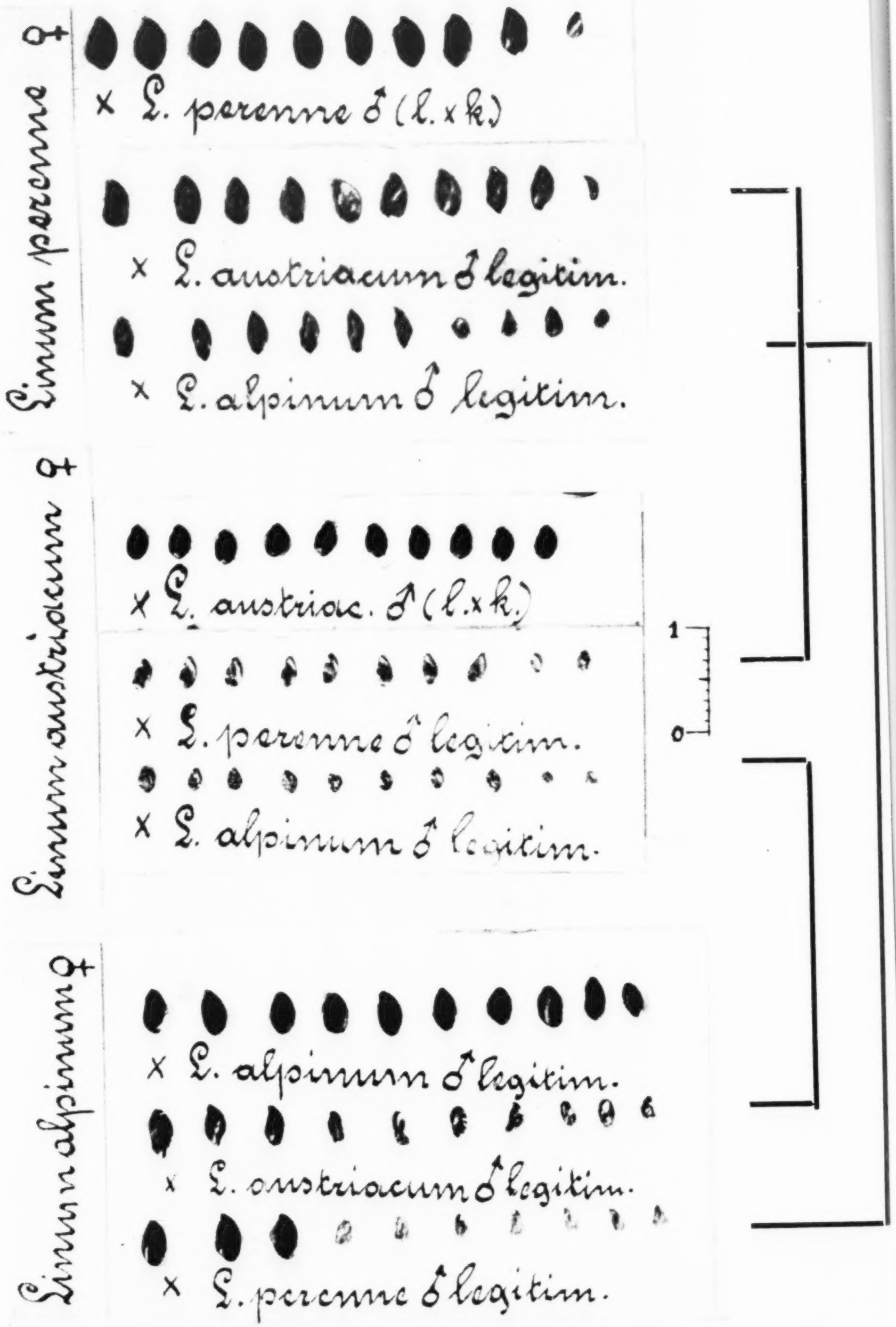
Such a view is untenable. Therefore, we can speak of genetical lethality or sublethality only in cases where an organism dies or shows deficiencies of development under optimal conditions for the species or variety.

There are few cases known of lethality genetically conditioned, when we define lethality and sublethality in this way, in the *vegetative* period of phanerogams. Mostly there is the question of chlorophyll deficiencies, which are transmitted according to the simple monohybrid scheme.

Furthermore, we may speak of a sublethal factor in a Sordago strain of *Mirabilis jalapa*, where Correns regularly observed disturbances in the development of some of the palisade-cells, although the total development of the plant was only slightly injured by these disturbances.

Embryonic Death of Seeds

More frequently genetic lethality is considered to exert its effects in the embryonal period of development. But the observation that some biotypes die regularly in the seeds is not conclusive proof of genetic lethality. Such seeds may be viable, but their substratum, the mother-plant, may not be qualified to afford them normal development. Because embryo and mother-plant are mutually adapted in their ontogeny, disturbances in the physiological relations can be produced by genotypical differences that are the reason for the death of the embryo.


Linum perenne ♀
× L. perenne ♂ (l. × k.)
× L. austriacum ♂ legitim.
× L. alpinum ♂ legitim.
Linum austriacum ♀
× L. austriac. ♂ (l. × k.)
× L. perenne ♂ legitim.
× L. alpinum ♂ legitim.
Linum alpinum ♀
× L. alpinum ♂ legitim.
× L. austriacum ♂ legitim.
× L. perenne ♂ legitim.
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SEEDS OF RECIPROCAL CROSSES BETWEEN THREE SPECIES OF FLAX

Figure 5

In each group all ten seeds of a fruit are photographed in a dry state. The top row in each group shows the normal seeds produced by crossing within the species. ($l \times k$ indicates a cross between a long-styled and a short-styled strain.) The brackets on the right indicate the three reciprocal crosses. The hybrid seeds are mostly mere husks, though there is considerable variation in the degree of defect of reciprocal crosses. Only in the cross of *perenne* x *alpinum* (which are nearly related) have a few good seeds been obtained.

NORMAL AND HYBRID SEEDS OF L. PERENNE

Figure 6

Normal seeds of *L. perenne* above, and hybrid seeds obtained with pollen of *L. austriacum* below. The seeds are photographed after soaking. The testa of the hybrid seed is slightly transparent, allowing the outlines of the embryo to be seen in some cases. Figures 6, 7, 8, and 9 are all photographed in the same scale, enlarged nearly 4 times.

SPECIES-EMBRYOS AND HYBRID-EMBRYOS OF L. PERENNE

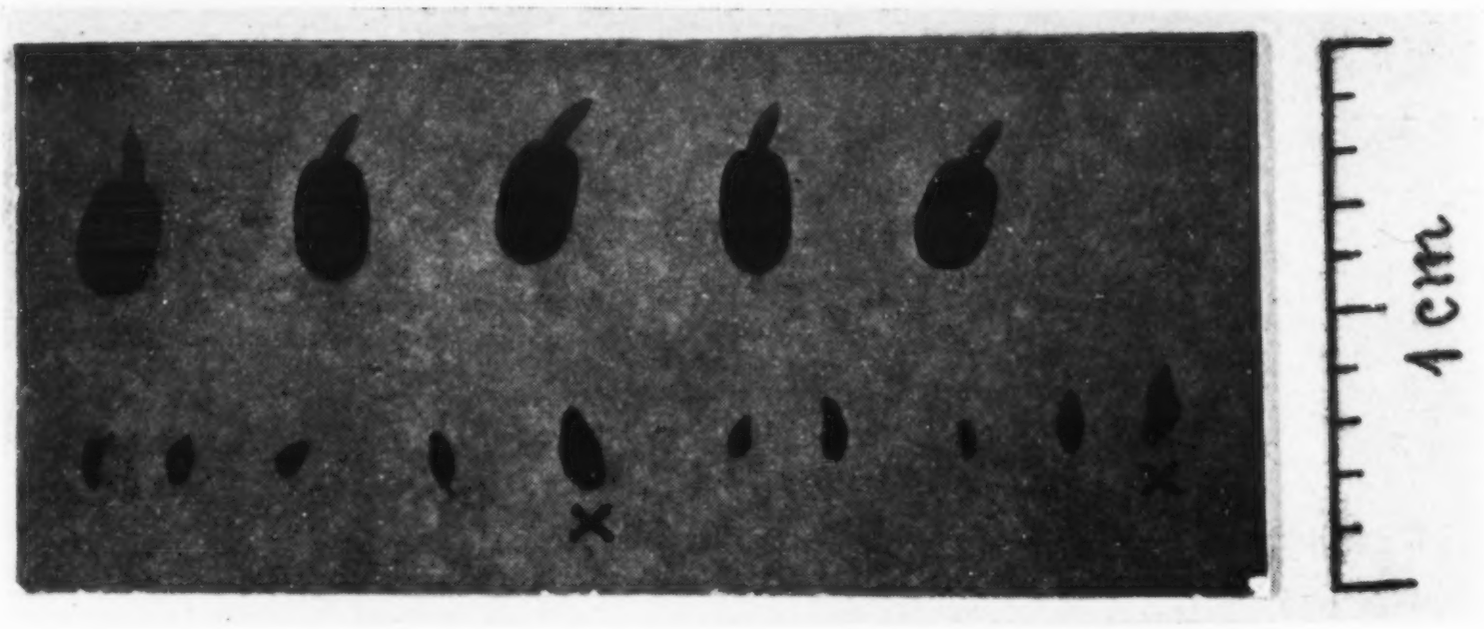
Figure 7

In the upper row are the normal embryos of *L. perenne*. In the lower row the embryos produced by pollen of *L. austriacum* are shown. The embryos have been prepared out of soaked and swollen seeds.

SEEDS OF RECIPROCAL CROSS

Figure 8

Normal seeds of *L. austriacum* are shown above, and below the seeds produced by pollen of *L. perenne*. This is the reciprocal of the cross shown in Figures 6 and 7. The hybrid seeds have a membraneous testa that is pigmented only on the spot where the tiny embryo lies.



EMBRYOS OF AUSTRIACUM AND HYBRID

Figure 9

Above are species embryos of *L. austriacum,* and below are embryos produced by pollen of *L. perenne.* The embryos marked with a cross are still enclosed by the tegmen and thus look larger than they really are. Note that these embryos are much smaller than those of the reciprocal cross (Figure 7). *Perenne* is evidently a better environment for the development of the hybrid embryos than *austriacum.*

In all these cases we are not able to give optimal conditions for the embryo and therefore it might be almost impossible to prove exactly the genetical basis of such zygotic lethality.

We can draw more definite conclusions about the embryos inhibited in the seeds, when we succeed in bringing to germination some of the embryos, and when they die, later on, as germinating plants, the influence of the mother-plant having ceased. Here may be mentioned the aurea-races of Antirrhinum[1], where the homozygotes die in part as white germinating plants, in part already in the seeds. Also we may mention the behavior of the germinating plants of certain varieties of maize, examined by Jones[6] and by P. C. Mangelsdorf, which in some races are hindered only in the vegetative period. We are justified in claiming genetic lethality in other races, where the embryos die before the seeds reach maturity. But Renner is wrong when he declares the defective seeds of certain hybrids of Oenothera to be unviable on account of the fact that these embryos never develop, but die in the seeds in earlier or later phases of development. In all these cases it is, as shown, almost impossible to prove genetic lethality. At most we can try to test whether they are not really viable, the failure of development being due only to somatical disturbances.

The experiments should be executed in the following manner: the embryos are to be separated from the mother-plant and put into other conditions before they die on the plant. It would be necessary to undertake premature birth and to observe the fate of the embryos, nurished on a fit substratum. If they develop, there are no lethal factors, and the death of the embryos is due to disharmonies in the developmental tendencies of the two inherited components united in the hybrid which arrest the development of the seed. However, the experiment is of importance only, if it turns out positively. If we do not succeed in bringing the embryos to development we cannot reach a certain conclusion regarding the viability or unviability of the embryos, as they might develop under different conditions.

Artificial Cultivation of Embryos

After a certain stage of development it is possible to take out some embryos from the unripe seeds and to cultivate them artificially. That discovery was announced by Hannig[4]

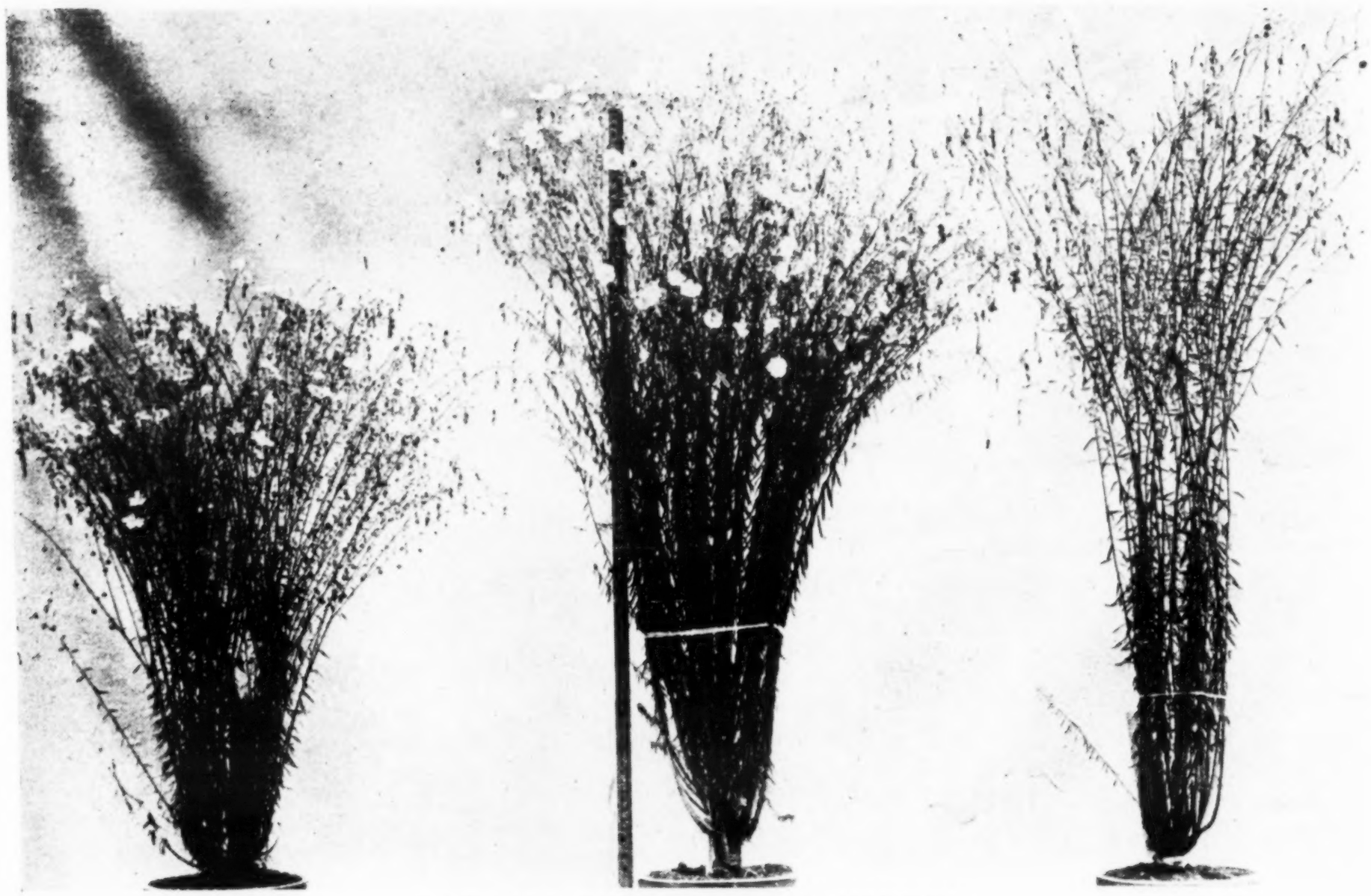
HYBRID EMBRYOS GERMINATING
Figure 10

On the Left—A hybrid embryo (green) shortly after its preparation out of an unripe fruit a fortnight old. *Center*—Embryo after 18 days in a sterile 10 per cent solution of cane sugar. It has turned white as normal embryos do in developing within the seed. *Right*—An embryo artificially cultivated in sugar solution a few days after germination. The usual failure to develop within the seeds is not caused by any inherent lethality of the hybrid, but is due to the fact that the mother-plant does not offer a satisfactory environment for its development.

in 1904 with seeds of Crucifers. Dieterich[3] repeated these experiments extending them to a greater number of families of plants. But he succeeded in bringing to a normal development only the embryos of Cruciferes and Gramineaes. My experiments were caused by the observation that a great number of species-crosses, which I made between different mostly heterostyled species of Linum, produced normal fruits, but the seeds contained embryos that were extremely defective or actually dead. In the reciprocal crosses, the embryos were inhibited to a different degree (Figure 5). As an example I may cite the results of a reciprocal cross between *L. perenne* and *L. anstriacum*.

When I pollinated *L. perenne* legitimately with *L. austriacum,* normal looking fruits were produced, but they contained seeds that seemed to be dead. The best developed seeds were as large as the normal species-seed of the mother plant, but they were very much shrunken. They were about half as heavy as the normal seeds (Figure 6). Having been sown out upon moist blotting-paper into Petri-dishes not one germinated. But they contained embryos which could easily be separated out after the seeds had been kept moist for some time. The embryos were different in their dimensions, but they were always smaller than the normal species embryos. They were white like ivory and had the same hard consistence just as the normal species embryos had, but the cotyledons were deformed in most cases (Figure 7). The best developed seeds did not always contain the biggest embryos. Laid upon damp blotting-paper, the embryos, prepared out of the seeds, germinated a few days later. However, from the first the development proceeded slowly after the germination had taken place. But, after having withstood the first inhibitory influences of development, and after having been brought into the open air, they developed and became quite normal plants, in most cases even stronger than their parents. They blossomed abundantly and produced fruits when they were pollinated in a legitimate way.

Also I nearly always obtained fructification when *L. austriacum* was legitimately pollinated with pollen of *L. perenne.* But these fruits were smaller than the species fruits of *L. austriacum* and weighed only a fourth as much. They usually fell off from the mother plant before they ripened. It was easy to compress the fruits, whence one could conclude that they did not contain normal seeds. All these seeds were membranous and their tests was not colored (Figure 8). Only the place where the tiny embryo had laid had become a little brown. The weight of these seeds was only about the thirteenth part of that of the species seeds. Of course, they did not germinate when kept moist, only where the embryo was situated they swelled a little, and if one opened the testa here one could very cautious-



PARENT SPECIES AND HYBRID

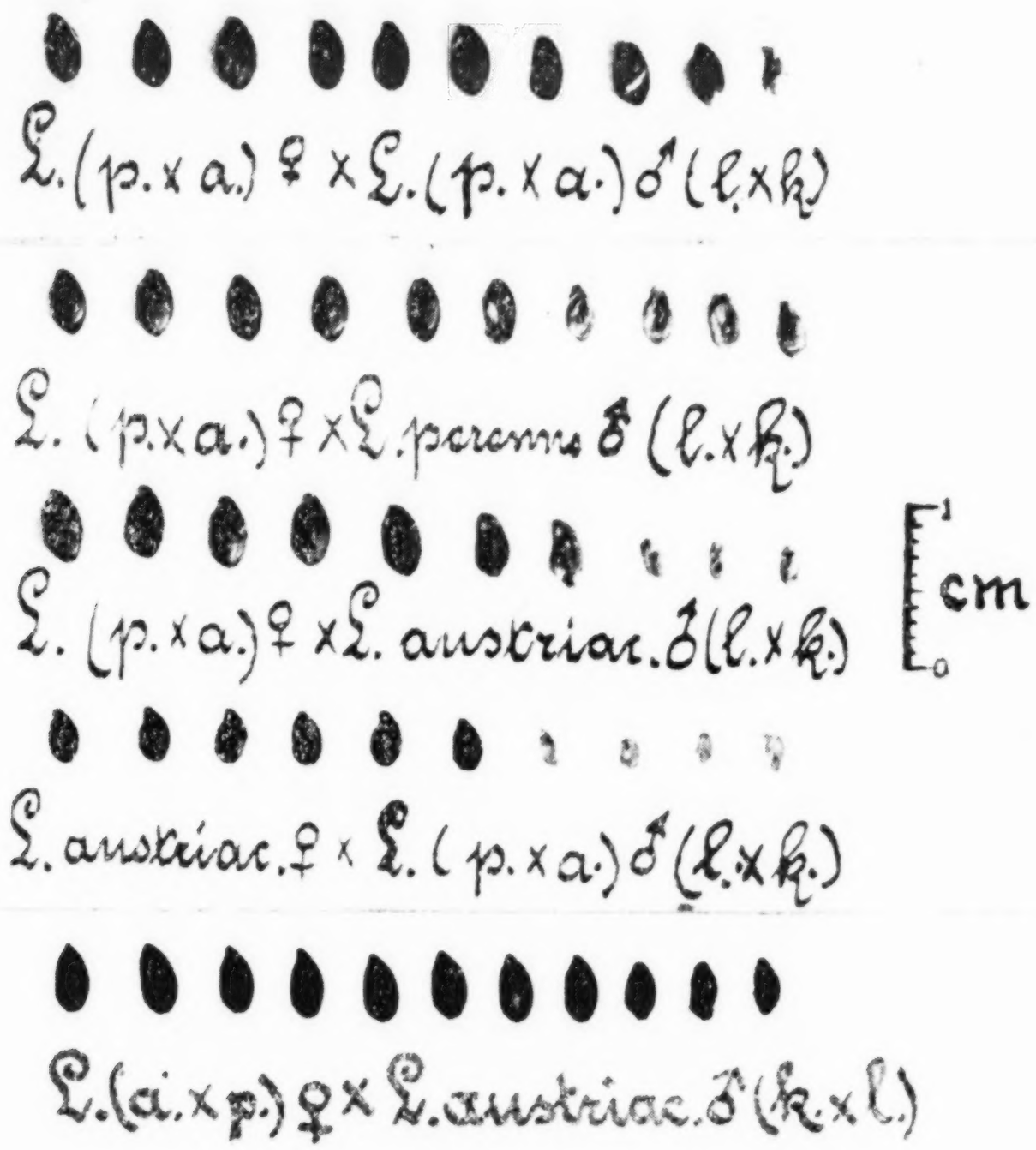
Figure 11

On Left—*L. austriacum*. Center—*L. (austriacum x perenne)*. Right—*L. perenne*. The plants shown here were grown in the garden and were only potted just before being photographed. The hybrid plant therefore shows a more robust development than the plant illustrated in Figure 4, which was raised in a pot.

ly press out the embryo (Figure 9). Usually the embryo is still enclosed by the tegmen, mostly it is 1½ mm. long and still quite green. Consequently its development had stopped at a state that normal seeds of the species reach in two to three weeks. I tried to bring these embryos to germinate directly. But all these experiments were in vain.

Therefore, I prepared the embryos out of the unripe fruits, when they were about a fortnight old and had just begun to change color, and I nourished them artificially. Mostly I left them in the tegmen, and then they were put by fives at the same time into a little test-glass, that was 8 cm. high and had a light diameter of 1 cm. The lowest third part was filled with cotton wadding, watered by a solution of 10-15% cane-sugar. The test-glasses were shut by a stopper of cotton and after having been filled with the solution of cane-sugar, they were sterilized. It is not necessary to say that the embryos should be brought into the test-glasses as sterile as possible. For all that, a part of them became mouldly after some time and then the culture was lost. But another part remained free from the mould.

After remaining in the sugar solution for a fortnight the embryos lost their green color and became white and hard like the normal ripe embryos. Then they were taken out of the test-glasses, washed in running water and laid on a moist blotting-paper for germination. The germination began after only a few days (Figure 10). Hypocotyl and root began to stretch out and the first named and the cotyledons became green again. Planted into flower-pots, the young plants, carefully cultivated, developed well. Unfortunately there were some difficulties in wintering and I succeed-



VIABLE SEEDS IN THE NEXT GENERATION

Figure 12

Seeds produced by intercrossing hybrids between *L. perenne* (indicated by *p*) and *L. austriacum* (indicated by *a*), and in back-crosses with parent species. Part of the seeds of a fruit are always quite normally developed and germinate spontaneously. The incompatibility that prevented the development of the seeds of the original cross has been broken down, and the making of later crosses is much facilitated. The practical and theoretical possibilities of this technique are obvious.

ed in keeping alive only one of the hybrids. Figure 4 shows the hybrid in the third year of its life in time of blooming. In the meanwhile it has been propagated by cuttings and absolutely resembles the hybrid L. *perenne* × *austriacum*. Legitimately pollinated with pollen of *L. austriacum* or *L. perenne* it fertilized well. I was successful in what was first thought to be impossible, and what Kőlreuter had tried in vain. Even the tiny embryos of the cross *L. austriacum x perenne* could be brought to ripeness, germination and normal development. With this experiment it is proved that disturbances in development are caused by the mother-plant and that it is possible to keep alive the hybrid-embryo when it is withdrawn in time from the fatal influence of the mother.

After having found the two reciprocal hybrids between *L perenne* and *L. austriacum*, there must be a second possibility to show that indeed only the disharmony in the relations between the embryo and the mother-plant are the cause for the marked deficiencies. For, if the hybrids are pollinated legitimately with each other, one had to suppose that the F_2 embryos developed normally, because the F_1 mother-plant represented a substratum which is genetically more nearly related to them. Indeed that was the fact. Not only when the F_1 hybrids

were crossed with each other, even by back-cross between hybrids and parents, normal seeds were produced that germinated spontaneously and yielded quite a normal F_2-generation. (Figure 11).

Now it is possible to backcross with the *austriacum* parent, and in this way we can enrich the hybrid with *austriacum*- "Blood." Then we can examine how long it will require to obtain entirely normal embryos by pollination with *L. perenne*. These experiments are in progress.

After having seen the results of the described experiments we can scarcely doubt that we shall succeed in bringing to development by the way of artificial premature birth a large number of combinations heretofore considered unviable. For other crosses in the genus of *Linum* where I found defective embryos, (e. g. the combination *L. austriacum* × *L. alpinum*, or *L. viscosum x L. hirsutum* and others). I think it only a question of technique. In this connection it is also remarkable that while Renner still holds to the assumption of the unviability of certain *Oenothera*-combinations, his pupil, Hiorth, who has investigated the embryology of these combinations, wrote in 1927[5]:

> After Laibach's researches one cannot say that it is impossible that three-week-old embryos of lutescens and suaveolus cannot be successfully brought to maturity, for there is often a physiological incompatability between embryo and mother plant. In the case of valens and flavens homozygotes of lamarkiana and suaveolus an investigation might not prove fruitless.

Of course, it would be of great interest if we really would succeed in raising some of these *Oenothera*-crosses.

In any case, I deem it advisable to be cautious in declaring combinations between higher plants to be unviable after fertilisation has taken place and after they have begun to develop. Experiments to bring the aborted seed to development should always be undertaken, if it is desirable for theoretical or practical reasons. The experiments will not always be successful, but many a result might be obtained by studying the conditions of ripeness of the embryos and by finding out the right time for the preparing out of the seeds.

In future, however, it will be necessary to push on still farther. Many combinations, which are perhaps viable, are only sure to fail because the fertilization is hindered by any disturbances of the male haplont. Till now we have hardly tried to interfere in regulating this matter, but to me it does seem not to be without prospects.

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TRIPLETS IN A RELATIVELY HOMOZYGOUS FAMILY

R. Ruggles Gates

University of London

SIBS A PLENTY—BUT TOO MUCH ALIKE!

Figure 13

These triplets have nine brothers and sisters, so that there is ample material to apply Muller's method of classification. The fact that the parents were much alike, and apparently homozygous for several characters has resulted in an unusually uniform family. The question of whether we have here fraternal triplets, identical twins and a "brother," or identical triplets is thus difficult to answer.

THE present case of supposed identical triplets is worth publishing in order to emphasize a principle which has been generally overlooked in the explanation of identical multiple births. This case of triplets occurred in the Miller family, the parents being of Austrian birth and apparently Nordic ancestry. They emigrated to Canada and settled at Stony Plains, Alberta, 20 miles from Edmonton, rearing a family of twelve children, ten boys and two girls. Three of these boys are the triplets in question, now eight years of age, the rest are single births. I visited them in July in company with Professor J. C. Fryer of the University of Alberta. Seven of the children are shown in Figure 13 and the triplets in Figure 14.

The father has pure blue eyes; his hair is now grey but was formerly light in colour, even lighter than that of his wife. The mother also has light hair, very light yellowish brown. Her eyes are hazel, with pale yellow pigment

SIMILAR—BUT IDENTICAL

Figure 14

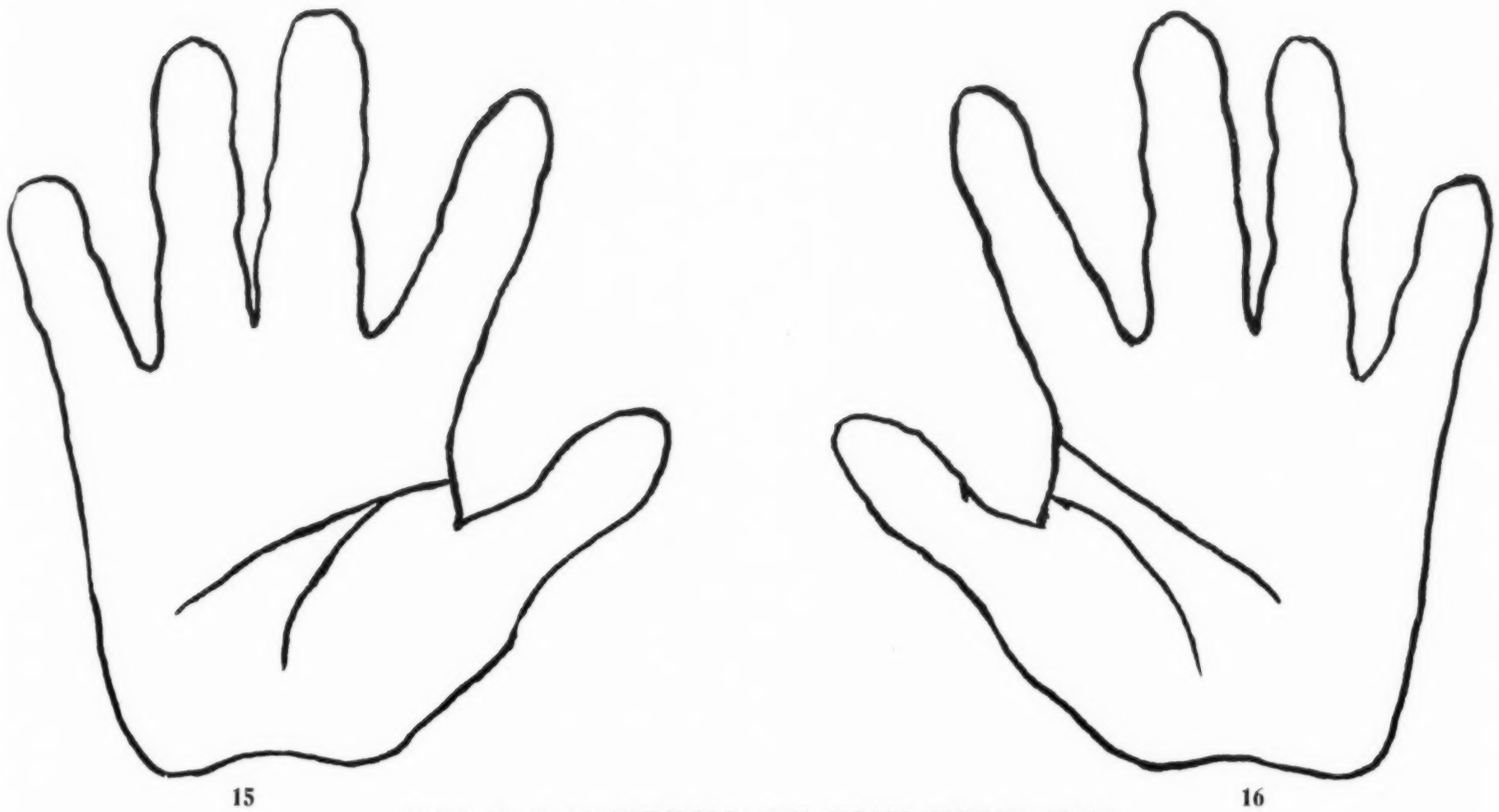
The fact that the triplets' brothers and sisters are very much alike, in hair and eye color especially, makes it uncertain whether they are to be considered identical or fraternal.

scattered lightly over the whole iris. No details regarding their parents were obtainable, but two of the wife's brothers had dark hair and one light. She may then be regarded as a recessive segregate.

All the children were examined except one son and one daughter. They were all alike in eye color and hair characters, and were intermediate between the parents in these respects. The triplets and four other brothers had eyes which were blue, but when closely examined showed a touch of yellow pigment around the pupil. Their hair was very fair, almost white, being somewhat darker in the older sons. Two elder brothers than those shown in the photograph (Figure 13) were found to have essentially the same hair and eye color (blue with a pale yellow ring around the pupil), but their facial features were very different. The daughter examined had blue eyes and flaxen hair. She wore glasses, indicating some slight inherited ocular defect.

The extraordinary similarity of this large family in eye and hair color then was due to the fact that the parents were both extracted recessives, one nearly and the other quite at the bottom of the color series. Their children must therefore resemble each other in these features, except for the slight degree of variation introduced by the small amount of yellow pigment present in the mother's eyes. This probably represented a factor for which she was heterozygous, the allelomorph being pale blue. On the other hand, the facial differences shown by two of the sons indicates that the parents were heterozygous for various factors which determine the features.

A part of the similarity between the triplets (Albert, George and Edward) can thus be accounted for. They might, however, still be monozygotic or iden-



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PALM PATTERNS OF THE TRIPLETS

Figures 15 and 16

Four of the hands are alike in palm main line pattern (Figure 15), but in Edward's left hand and George's right the lines do not meet as shown in Figure 16.

tical. They were of good size for their age, strong and vigorous. I was told that one weighed a pound heavier than the others, but psychologically they were very much alike. They always played together and imitated each other. If one kicked a tin can, the others must needs go and do the same thing.

I was, unfortunately, not able to get finger-prints, but an examination of the palm patterns of the triplets disclosed certain differences. Four of the six hands were alike in the contour of their main lines, as shown by the diagram in Figure 15, but Edward's left hand and George's right differed in that these two lines did not meet, as shown in Figure 16.

Examination of the ears disclosed another difference. Albert had a small Darwin tubercle on his right ear, which was not present in the other five ears. George had a ridge in the upper part of his left ear, which was not found in the others. A thorough examination might have disclosed other differences, but these were the only ones which were noted.

In the result, I am not entirely convinced that these are identical triplets, despite their striking similarity. This case illustrates the importance of noting the range of variation in the brothers and sisters of supposed identical twins or triplets and getting some indication of whether the parents are likely to be heterozygous in many characters.

Degree of similarity has hitherto been the sole criterion in addition to chorion and placental characters, as to whether similar twins or triplets are really identical, i. e., monozygotic. But it is obvious that the significance of such similarity will be emphasized if it occurs in a family in which the other sibs show great differences, and diminishes in a family where they show many similarities owing to the relative homozygosity of the parents. We are so accustomed to see hybridity in the human race that we fail to realize that if parents of any family were both homozygous in all their characters the children would be as much alike as peas in a pod, or at least as maize plants in a row.

Komai* has recently published photographs of a set of identical triplets, but without describing them. He gives a careful review of the criteria for distinguishing identical twins and points out that in the Mongolian race, where the eye color and hair color and form are practically uniform, it is more difficult to distinguish identical twins from fraternal twins than in other races, where eye and hair characters are variable. If the sibs of the present triplets had differed markedly in eye and hair color, the evidence for their monozygotic origin would have been much stronger. There appears to be no single absolute criterion, not even that of one chorion or placenta, so that each case must be decided on a balance of evidence. No doubt the examination of finger, palm and sole prints would settle the present case, especially after the triplets have grown to adulthood. I am glad to hear that such a study is now being undertaken.

The importance of resemblances or differences in the sibs in determining the identity of twins is recognized in the formula developed by Muller in this Journal for December, 1925, and is further brought out in the discussion with Miss Burks in the number for June, 1926.

*Komai, Taku. 1928. Criteria for distinguishing identical and fraternal twins. *Quart. Rev. of Biol.* 3:408-418, figs. 8.

Books Received

BOOKS are acknowledged in this column as received, and such acknowledgment must be regarded as sufficient return for the courtesy of the sender. As far as space permits, books that contain material of special interest to the readers of the Journal will be reviewed in later numbers.

OBSERVACIONES SOBRE AGRICULTURA: By Prof. Dr. Alberto Boerger, Director del Instituto Fitotecnico y Semillero Nacional. 576 Pages. Montevideo, Imprenta Nacional, 1928.

Fifteen years of agricultural improvement in Uruguay.

THE STATISTICAL ABSTRACT OF THE MINISTRY OF AGRICULTURE AND FORESTRY, 1927; Section of Statistics, Ministry of Agriculture and Forestry, Japan. 220 Pages. Price 2.10 yen. Tokyo, The Tokyo Statistical Association, 1928.

220 pages of figures—and more figures on everything raised, fished or hunted in Japan, alphabetically arranged from *Abalone* to *Yellow-tail*.

PIETRO NATI, Memoria Sull'Agrume Bizzarria, Ristampa Integrale del Testo Latino con Traduz. e note del Dott. Attilio Ragioniere. 64 Pages. Catania, Francesco Battiato, 1929.

A reprint of Nati's original description of the Bizzarria published in Florence in 1674, with an Italian translation and a note by the editor, Dr. Attilio Ragioniere.

LA SARABANDE ETERNELLE, Dialogues sur la Matière: By CHARLES BRUNOLD. 225 Pages. Seven Dialogues. Paris, Librairie Hachette, 1929.

The St. Vitus' Dance of the atoms and molecules appears as the stately sarabande!

SWEET PEAS, Their History, Development, Culture: By CHAS. W. J. UNWIN. 197 Pages. 12 Chapters. 19 Illustrations. New York, D. Appleton and Company, 1926.

GROWING UP, The Story of How We Become Alive, are Born and Grow Up: By KARL DE SCHWEINITZ. 111 Pages. 30 Illustrations. Price $1.75. New York, The Macmillan Company, 1929.

ORIGIN THROUGH EVOLUTION: By NATHAN FASTEN, Ph. D., Professor of Zoology in Oregon State Agricultural College. 456 Pages. 14 Chapters, Glossary. 75 Illustrations. Price, text edition, $3.00; trade edition, $3.75. New York, Alfred A. Knopf, 1929.

THE COWBIRDS, A Study in the Biology of Social Parisitism: By HERBERT FRIEDMANN, Amherst College. 421 Pages. 10 Chapters. 28 Plates, 13 Text Figures. Baltimore, Md., Charles C. Thomas, 1929.

PEAR GROWING WITH SELECTED BUDS

A 200-Acre Project in Bud Selection in Pears

S. MERRILL, JR.

California Packing Corporation

PICKING TIME IN A CALIFORNIA PEAR ORCHARD

Figure 17

Scene in an orchard of the California Packing Corporation. Similar to those which were surveyed to find superior trees.

WHEN an institution like the California Packing Corporation uses buds selected from trees of known record in the propagation of 200 acres of pear orchard, little question remains as to the great importance placed by our large fruit producers in the latest practices in orcharding. The California Packing Corporation is well known as the producer of the *Del Monte Brand* of canned fruits, vegetables and fish. During the last two years the Land Department of this corporation has made a special study to locate the best Bartlett pear orchards in California and the trees of highest record in these orchards from which to cut bud-wood, and have developed on a ranch of the Alaska Packers' Association (a subsidiary company), a 200-acre orchard of blight-resistant pear stocks which is being topworked with the selected Bartlett buds. This orchard is located at Sacramento, California.

The officers of the above corporation have gone into this venture with a full knowledge relative to the controversy which exists between the opponents and proponents of "pedigreed trees" and "bud selection". They consider they are not taking a risk since in any

OFF-TYPE BARTLETT PEARS

Figure 18

A flattened irregular shaped type of the Bartlett pear. Branches bearing only such types of fruit were found. Several entire trees in one of the Santa Clara Valley groves bore similar off-type fruit until grafted over by the owner.

event they will hold their variety true to type and perchance may gain through increased production and vigor, and through improvement of quality.

Early in 1926 a comprehensive survey of Bartlett pear orchards was undertaken. Mr. A. D. Shamel, physiologist in charge of Fruit Improvement Investigations, United States Department of Agriculture (who is best known for his studies on bud selection for the improvement of citrus fruits) was asked to lay out a program of selection for the Bartlett pear. Mr. Shamel is also making selection studies in peaches in a large orchard owned by the corporation at Merced, California.

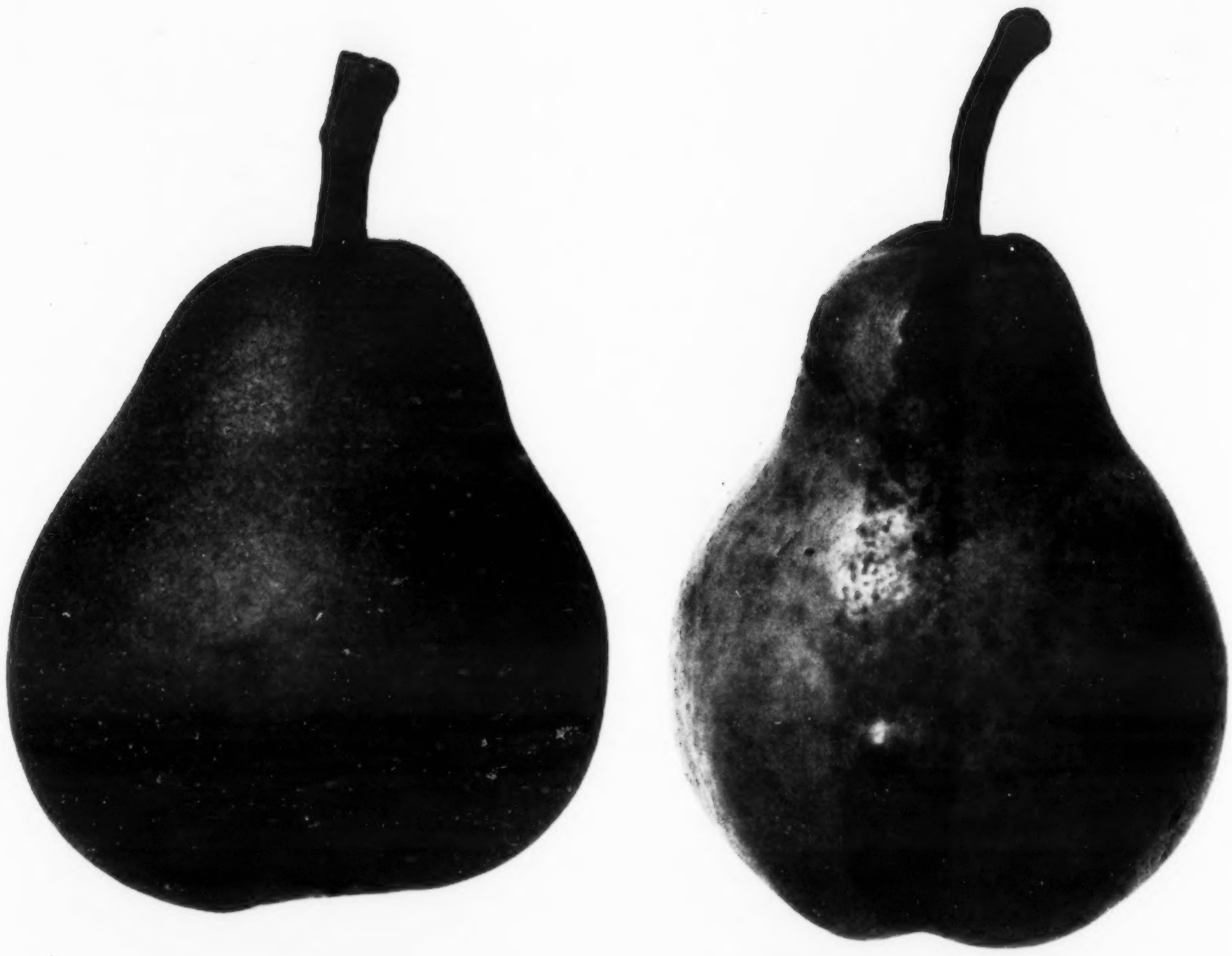
The pear bud selection work was outlined as follows: First the location of Bartlett pear orchards of known productivity and of high quality fruit of uniform character; second, the institution of an individual tree study of thousands of trees in the chosen orchards to select outstandingly productive and desirable trees; third, propagations from the selected trees.

In June, 1926, a trip was made by auto through three of the principal pear regions of California to make final selection of orchards suitable for the cutting of bud-wood. Included in this party were Mr. M. Jongeneel, manager of the Land Department, California Packing Corporation; Messrs. A. D. Shamel, C. S. Pomeroy and L. B. Scott of the United States Department of Agriculture; Mr. A. M. Jongeneel, superintendent of the West Sacramento Ranch, on which ranch the bud-wood is being used; and the writer as field man in the bud work. The following five orchards were chosen for individual tree records:

(1 and 2). Two orchard blocks along the lower Sacramento River near Courtland were chosen from several inspected in this important pear section. The Sacramento River pears were found to be smooth and bright and to have good finish, though the fruits are somewhat shortened, with a thicker neck than is desired by canners. One block chosen, a seven-acre planting of 40-year-old trees yielded for the year 1926 32 tons to the acre. The other block, consisting of two acres of approximately 70-year-old Bartletts, produced at the rate of 45 tons to the acre. These are extremely large, fine trees which have withstood at least one severe flood of the Sacramento River in addition to having been exposed to constant attacks of pear blight, known to this region for many years.

(3). A large acreage of pears is grown in the Santa Clara Valley. Among the best of the orchards in this valley is a 39-acre block three miles from the town of Santa Clara. This orchard, like most of the pear orchards of the region is comparatively free from fire blight, which is generally so destructive in California. The trees, though not large in size, have an excellent production record. Records kept from 1891 (when the trees came into bearing) to 1927 show that the orchard has yielded an average annual crop of approximately thirteen tons per acre. The 1927 crop for this orchard was approximately 1,200 tons or 30 tons per acre. Pears from this orchard lacked a little in desirable brightness of skin and were somewhat less perfect in shape than those from certain of the other orchards studied. The fruit from this block in common with most Santa Clara Valley Bartletts is used by the canneries.

(4 and 5). The Lake County district north of San Francisco Bay is a comparatively small pear producing region which grows pears of a very excellent quality. Two orchard blocks were chosen for study, one a fourteen-year-old planting of approximately fourteen acres and the other an 11-acre block of trees of mixed ages. The young trees making up the first block were excellent in form, vigorous, and were producing the finest quality pears of any seen in the work. The average yield for 1926 was twelve tons. The trees in the other block chosen were not as uniform as could be desired but



VARIATIONS IN BARTLETT PEARS

Figure 19

Left—A small branch bearing only heavily russeted fruit of distinctive shape was discovered. *Right*—A normal Bartlett pear except for a slight russet streak.

certain outstandingly good trees were noted. They produced approximately 17 tons to the acre.

More intensive studies followed this initial survey. Each of the above-mentioned blocks was mapped and detailed notes were taken on each of 6,613 trees. The same procedure was repeated in 1927 on 4,789 of the originnal 6,613 trees. The following characteristics of tree and fruit were taken into account: productivity, size and vigor of the tree; size and appearance of the fruit; presence or absence of pear blight; and notes on any outstanding features. The uniformity of the fruit was also noted, especially in the final selection of trees as sources of bud-wood. An average of three trees out of every one hundred was selected during the summer of 1926. However, after the recheck was made in 1927 the selected list was reduced to 1.4 per cent of the total. Sixty-eight trees were thus finally selected in 1927.

The individual check of the trees brought to light several unsuspected facts about certain orchards. The Santa Clara orchard, which has given fine yields for the last 35 years, does not contain many large trees, but it was found that 94 per cent of its trees graded as either normal or exceptional in productivity. It is apparently this high average productivity rather than individual excellence that has made

this orchard block so productive. One of the orchards along the Sacramento River which at first appeared very uniform actually contained twelve per cent of replants. This was probably largely the result of the ravages of pear blight in past years. One of the Lake County orchards proved to have 26 per cent of comparatively small trees but produced well in spite of this. It is interesting to speculate on what the production might be were this 26 per cent of small trees normal in size and productivity.

During the course of the work as the trees were given individual examination many minor variations of tree and fruit were noted. In addition several very striking variations were discovered. Special note was taken of these as they gave indications of being true mutations or bud sports. In some cases branches or even entire trees bore large quantities of distinctly off-type fruit.

To test out whether these striking variations are of a permanent nature, bud-wood was sent in 1926 and 1927 to Mr. L. B. Scott, pomologist in charge of root stock investigations, United States Department of Agriculture, Shafter, California. Mr. Scott propagated the variations in order to determine the permanence of the various fruiting characteristics.

The bud-wood from the selected Bartlett trees was cut in June, 1927. Approximately 100,000 buds were obtained which were sufficient to top-work 90 acres of the stocks already growing in orchard location at the West Sacramento Ranch. The stocks of this orchard were chosen after careful consideration of the best information relative to the prevention of fire blight infection in roots and framework. Three stocks have been used; namely, *Pyrus calleryana, P. ussuriensis,* and French (*P. communis*), the majority being *P. calleryana.* All the trees from which the bud-wood is being cut are growing on French roots. For the trunk and framework the blight resistant variety, Old Home, introduced by Professor F. C. Reimer of Oregon Agricultural Experiment Station has been used throughout the planting. A second large propagation with selected buds was made on the remainder of the 200 acres of orchard stocks in the summer of 1928, at which time the major part of the work was completed. These buds used in 1928 were obtained from the 90 acres of budded stock of the previous year's propagation. Buds obtained from each district have been kept separate in the propagation, although no attempt has been made to keep separate the progeny of each selected "mother" tree. Reports of the fruiting of this orchard should be of interest to fruit growers and other workers in the horticultural field.

Delays in Production of Simplified Herediscope

As often happens in the development of a new device, unforeseen delays have prevented the distribution of the simplified Herediscope as promptly as we had expected when its production was announced in the March number. The Herediscope involves a novel combination of parts that has prevented its manufacture as originally planned, but the difficulties have been met, and before the appearance of the next number of the JOURNAL we hope to be able to ship their Herediscopes to those who have ordered them.

A 2N-1 CHROMOSOMAL CHIMERA IN MAIZE

BARBARA MCCLINTOCK
Botany Department, Cornell University

WHILE investigating the chromosome numbers in an F_2 generation of a cross of triploid maize *(Zea mays)* by diploid maize, an individual appeared whose microsporocytes showed a $2n - 1$ chromosome complement. The diploid chromosome number in maize is 20. Sporocytes of such plants normally show 10 bivalents at metaphase of the first meiotic division.

The presence of sporocytes showing only nine bivalents and one univalent (see Figure 20) in the first aceto-carmine smears led to a further investigation of the chromosome complement in other parts of the tassel. The plant was very small and the tassel poorly developed, but approximately 150 clear figures were obtained from several different regions of the tassel. In all cases the sporocytes showed clearly 19 chromosomes, usually in the form of nine bivalents and one univalent.

In anaphase the components of the nine bivalents disjoined and passed regularly to the two poles. The univalent usually lagged at the equator after the bivalents had disjoined, or lagged and split, the halves very frequently being eliminated from the reorganizing telophase nuclei.

Several root tips were examined and all clear figures showed 20 chromosomes.

Such evidence points to the fact that early in the ontogeny of the upper part of this plant a chromosome must have been lost. Such occurrences are probably not rare, but their detection is, since there are so few cases mentioned in the literature*. Unfortunately, for some undetermined reason, the plant gradually died before maturing pollen.

LACKING A CHROMOSOME

Figure 20

Photomicrograph from an eight months' old permanently mounted aceto-carmine smear showing a late metaphase figure with nine bivalents and one univalent. Made with the aid of a Leitz "Makam" camera, a periplanatic ocular, 1.8 mm. N. A. 1.25 Spencer achromatic objective, and a Wratten green filter No. 56. Magnification approximately 650×.

*BLAKESLEE, A. F., and BELLING, J. Chromosomal chimeras in the Jimson weed. *Science*, 55:19-20.

ORDER OF BIRTH OF MENTAL DEFECTIVES

A Survey of 10,455 Retarded Children in the Public Schools of Massachusetts*

NEIL A. DAYTON

Director of Division of Mental Deficiency, Massachusetts Department of Mental Diseases

IN 1915 the first travelling psychiatric school clinic in Massachusetts was operated from the W. E. Fernald State School. By 1921 fourteen such clinics were in operation and in 1928 the fifteenth was added. By means of the travelling clinics a comprehensive psychiatric examination was provided for all retarded school children. This examination covered ten different fields, including the mental, physical, pedagogic, psychologic and social aspects. Approximately 6,000 examinations per annum are now being conducted by the clinics and up to the present date about 30,000 children have been examined. The following paper reports the findings in reference to Order of Birth resulting from a study of the first 10,455 examinations conducted by two of the clinics.†

The examinations in this study have been used to test the following commonly accepted theories:—

(1) That the mentally defective child tends to be the first born of the family, thereby inferring that mental deficiency is a result of birth trauma.

(2) That the mentally defective child tends to be the last born of the family, thereby inferring that mental deficiency is the result of an exhaustion process.

Intelligence of Children Examined

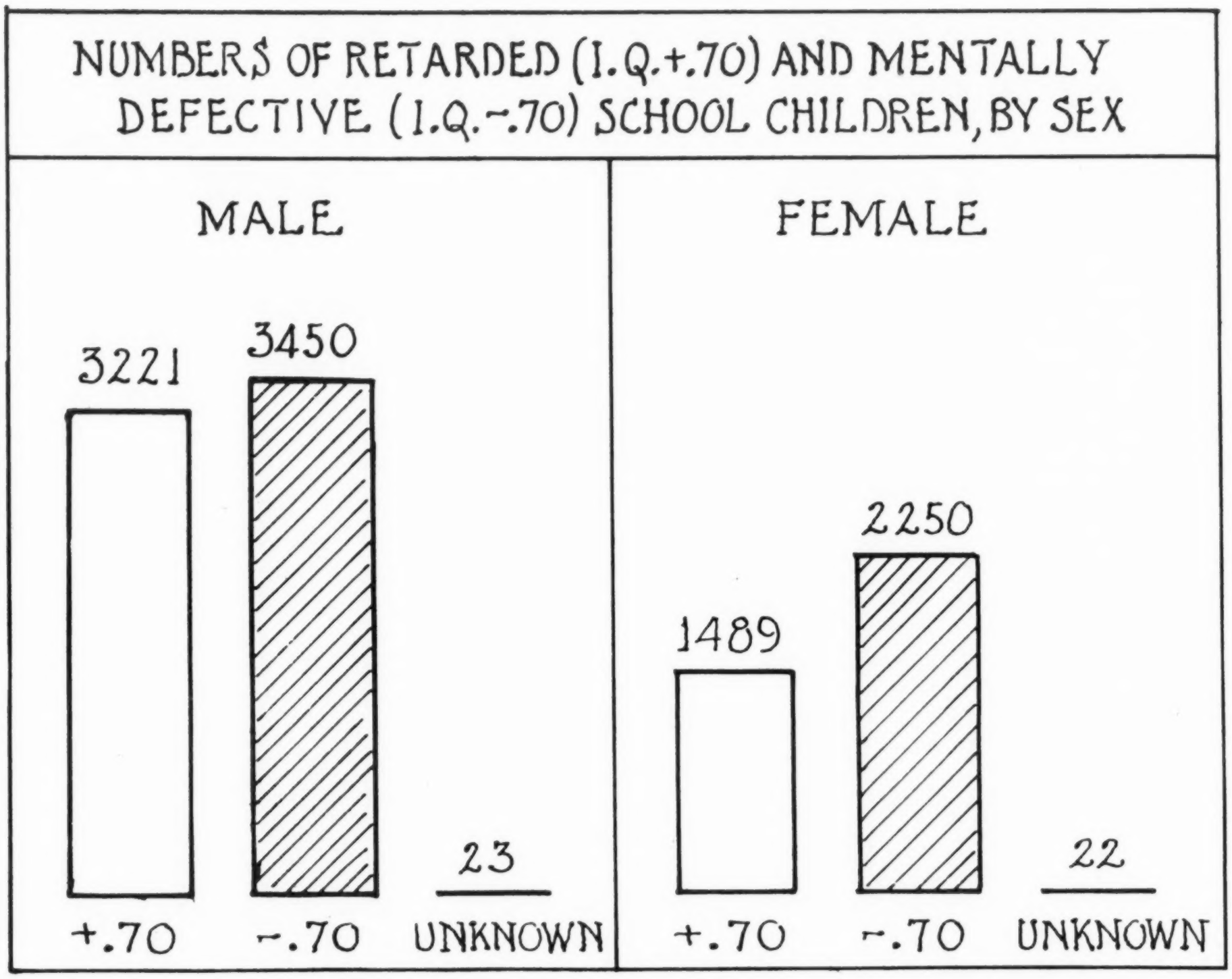
To avoid the possibility of mixed classifications insofar as intelligence was concerned, it was first necessary to divide the examinations according to intelligence groupings, as outlined in Figure 21 and Table I. Consequently, the retarded children examined were divided into two groups, by sex, (1) those with an intelligence quotient above .70 and (2) those with an intelligence quotient below .70. It will be observed that 6,671 males and 3,739 females, or relatively twice as many boys as girls, were examined during the period of this study. This striking difference will be discussed in other publications.

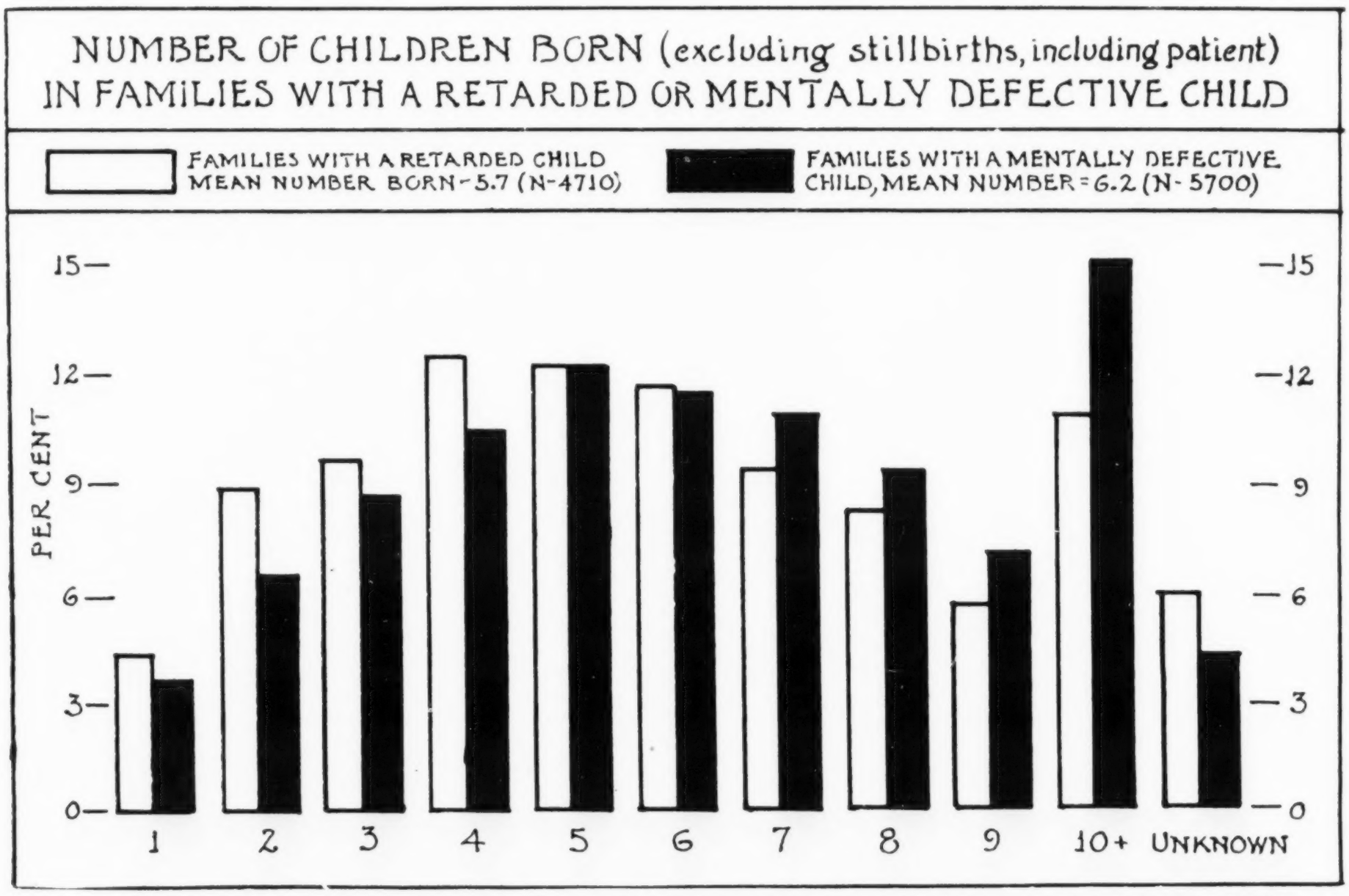
In Figure 21 and Table I it will be noticed that the total number concerned is 10,455. In all other graphs and tables, however, the forty-five unknown I. Q.'s are omitted, making a total of 10,410 cases under discussion throughout the remainder of the paper.

It is not necessary to go into the question of the validity of present day criteria in measuring mental ability. The Stanford Revision of the Simon-Binet, which was used in all tests, will give a rough estimate of what we are pleased to call "intelligence" at the present date. We know that within twenty-five years the 1928 conception of intelligence will be the "one-hoss shay" of psychology, and so must be satisfied with approximations in view of the non-permanence of our material.

*Massachusetts Department of Mental Diseases, Statistical Research Project No. 1, Article V. The writer was aided in the preparation of this paper by Eleanor Grenfell, A. B., and Helen H. Dolan, B. S., Assistants in Research, D. M. D.

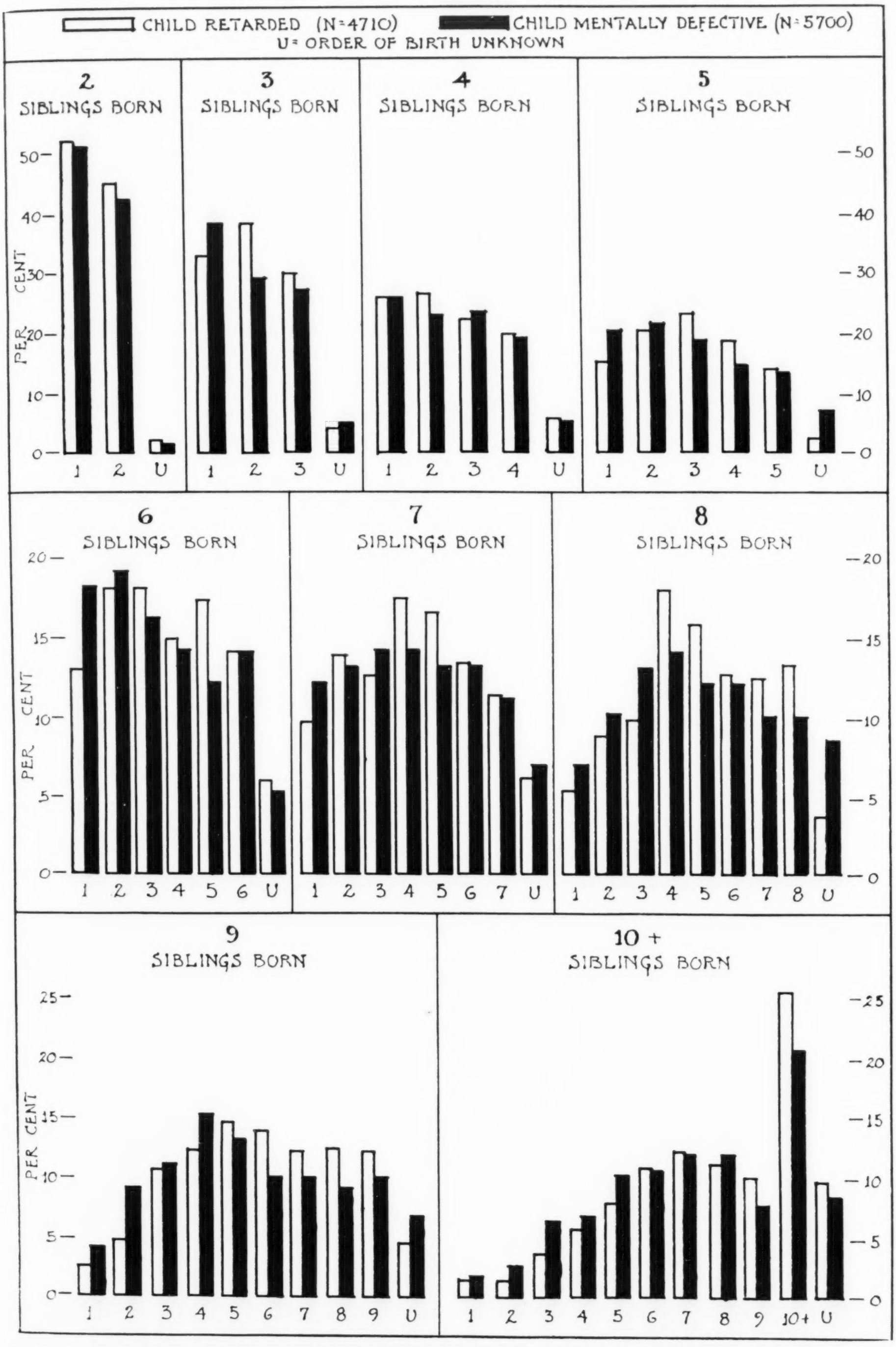
†These examinations were made by clinics in charge of Dr. Esther S. B. Woodward of the W. E. Fernald State School and Dr. Alice M. Patterson of the Wrentham State School for the years 1921-1927. Drs. Ransom A. Greene and George L. Wallace. Superintendents of these schools, have been very cooperative in rendering available to the Department the records of their travelling school clinics.





SEX DISTRIBUTION, AND SIZE OF FAMILIES WITH A MENTALLY DEFECTIVE CHILD

Figure 21


CHILD RETARDED (N=4710)
CHILD MENTALLY DEFECTIVE (N=5700)
U= ORDER OF BIRTH UNKNOWN
2 SIBLINGS BORN
3 SIBLINGS BORN
4 SIBLINGS BORN
5 SIBLINGS BORN
6 SIBLINGS BORN
7 SIBLINGS BORN
8 SIBLINGS BORN
9 SIBLINGS BORN
10 + SIBLINGS BORN
PER CENT
1 2 U
1 2 3 U
1 2 3 4 U
1 2 3 4 5 U
1 2 3 4 5 6 U
1 2 3 4 5 6 7 U
1 2 3 4 5 6 7 8 U
1 2 3 4 5 6 7 8 9 U
1 2 3 4 5 6 7 8 9 10+ U

ORDER OF BIRTH OF THE RETARDED OR MENTALLY DEFECTIVE CHILD IN FAMILIES OF DIFFERENT SIZE

Figure 22

Families of Different Size

Efforts were first made to answer questions (1) and (2) with reference to order of birth from the material of this sample. Does the mentally defective child come as the first or the last child? To answer this question it was first necessary to obtain (1) the number of families of different size, and (2) the order of birth in these families. Figure 21 and Table II show the size of family or the number of children born. In families having a retarded child the average number of children ever born (excluding stillbirths) was found to be 5.71 ± .04 (S. D.). In families having a mental defective, the number of children ever born was 6.24 ± .03 (S. D.). The difference was .53 and the σ = .05.

These figures are subject to error due to the method of sampling and to overlap of about ten per cent, but they reveal that the cases of lower mental grade tend to come from the larger families. It may be well to mention

Table I

Numbers of Retarded (I.Q. + .70) and Mentally Defective (I.Q. - .70) School Children, by Sex.

	Retarded (I.Q. + .70)	Mentally Defective (I.Q. - .70)	Unknown	Total
Male	3221	3450	23	6694
Female	1489	2250	22	3761
Total	4710	5700	45	10455

TABLE II

Number of Children Born (excluding stillbirths, including patient) in Families with a Retarded or Mentally Defective Child.

Number of Siblings Born in Families with a Retarded Child.

	1	2	3	4	5	6	7	8	9	10+	Unk.	Total
Male	142	300	337	404	392	399	313	250	176	336	160	3221
Female	68	121	124	185	185	148	131	137	96	179	115	1489
Total	210	421	461	589	577	547	444	393	272	515	261	4710

	MODE	MEDIAN	MEAN	S.D.
Male	4.49	5.88	5.64	± .05
Female	4.99	6.03	5.88	± .07
Both	4.49	5.92	5.71	± .04

Number of Siblings Born in Families with a Mentally Defective Child.

	1	2	3	4	5	6	7	8	9	10+	Unk.	Total
Male	116	224	307	343	447	378	378	330	242	545	140	3450
Female	93	149	188	254	249	275	243	209	163	319	108	2250
Total	209	373	495	597	696	653	621	539	405	864	248	5700

	MODE	MEDIAN	MEAN	S.D
Male	5.49	6.57	6.29	± .05
Female	6.49	6.50	6.17	± .06
Both	5.49	6.54	6.24	± .03

Table III—Order of Birth of Retarded or Mentally Defective Child

Number of Siblings Born in Family.	Order of Birth 1	2	3	4	5	6	7	8	9	10+	Unk.	Total
One												
Retarded												
Male	141										1	142
Female	68										0	68
Mentally Defective												
Male	116										0	116
Female	93										0	93
Two												
Retarded												
Male	152	139									9	300
Female	68	52									1	121
Mentally Defective												
Male	116	104									4	224
Female	77	71									1	149
Three												
Retarded												
Male	113	107	102								15	337
Female	38	48	36								2	124
Mentally Defective												
Male	122	84	84								17	307
Female	68	62	49								9	188
Four												
Retarded												
Male	105	111	91	77							20	404
Female	48	44	42	40							11	185
Mentally Defective												
Male	80	83	89	67							24	343
Female	76	58	55	50							13	252
Five												
Retarded												
Male	52	79	96	80	56						29	392
Female	36	42	46	31	26						4	185
Mentally Defective												
Male	92	98	88	74	62						33	447
Female	57	56	49	35	36						16	249
Six												
Retarded												
Male	51	62	72	65	65	60					24	399
Female	21	30	26	16	30	15					9	148
Mentally Defective												
Male	81	79	62	55	47	56					18	378
Female	58	44	45	38	33	40					17	275
Seven												
Retarded												
Male	25	42	36	53	59	41	37				20	313
Female	17	19	19	24	14	18	13				7	131
Mentally Defective												
Male	41	50	48	59	52	53	45				29	378
Female	36	35	40	32	32	29	24				15	243
Eight												
Retarded												
Male	13	20	26	45	41	31	36	33			11	256
Female	8	15	13	25	21	19	13	19			4	137
Mentally Defective												
Male	25	32	44	48	47	38	32	39			25	330
Female	15	24	28	28	20	30	24	19			21	209
Nine												
Retarded												
Male	5	8	18	19	23	22	20	27	27		7	176
Female	2	5	11	14	17	16	13	7	6		5	96
Mentally Defective												
Male	10	22	26	38	28	28	28	21	25		16	242
Female	6	16	18	23	24	15	16	16	17		12	163
Ten -												
Retarded												
Male	5	4	13	22	28	38	40	40	36	82	28	336
Female	2	3	6	8	13	18	23	18	16	49	23	179
Mentally Defective												
Male	10	15	31	33	53	66	61	68	45	123	40	545
Female	7	6	24	25	35	28	43	36	23	63	31	321
Unknown												
Retarded												
Male	0			1							165	166
Female	1			0							114	115
Mentally Defective												
Male	0					0					108	108
Female	1					1					138	140
Sub-Total												
Retarded												
Male	662	572	454	362	272	192	133	100	63	82	329	3221
Female	309	258	199	158	121	87	62	44	22	49	180	1469
Mentally Defective												
Male	673	567	472	374	289	241	167	128	70	123	314	3418
Female	494	372	308	231	180	143	107	71	40	63	273	2282
TOTAL	2138	1769	1433	1125	862	663	469	343	195	317	1096	10410

that this overlap or reduplication was due to the fact that it was not possible to obtain the exact number of families. Consequently we have been forced to substitute "children" for "families". After giving due consideration to the matter, however, we believe that this failure makes no appreciable difference in the final result.

Order of Birth

The next step was to take the families of different size and investigate the order of birth. Figure 22 and Table III show the order of birth in families having from two to ten or more children. There is no uniformity in these results. That is, there is no evidence that the feebleminded child tends to be either the first or the last in the family. If anything, there appears to be a slight tendency for the feebleminded to occur in the middle of the family, particularly in the larger families.

Summary

I. According to this study, the order of birth of the retardate or mentally defective child is apparently of little significance.

II. Families having a mentally defective child (mean = 6.24 ± .03 S. D.) are larger than families having a retarded child (mean = 5.71 ± .04 S. D). These figures include both complete and incomplete families.

Mathematical Mysticism

SCHLIEPER, H., DAS RAUMJAHR. 360 pages. Published by Eugen Diedericks, Jena 1929. Price $4.44.

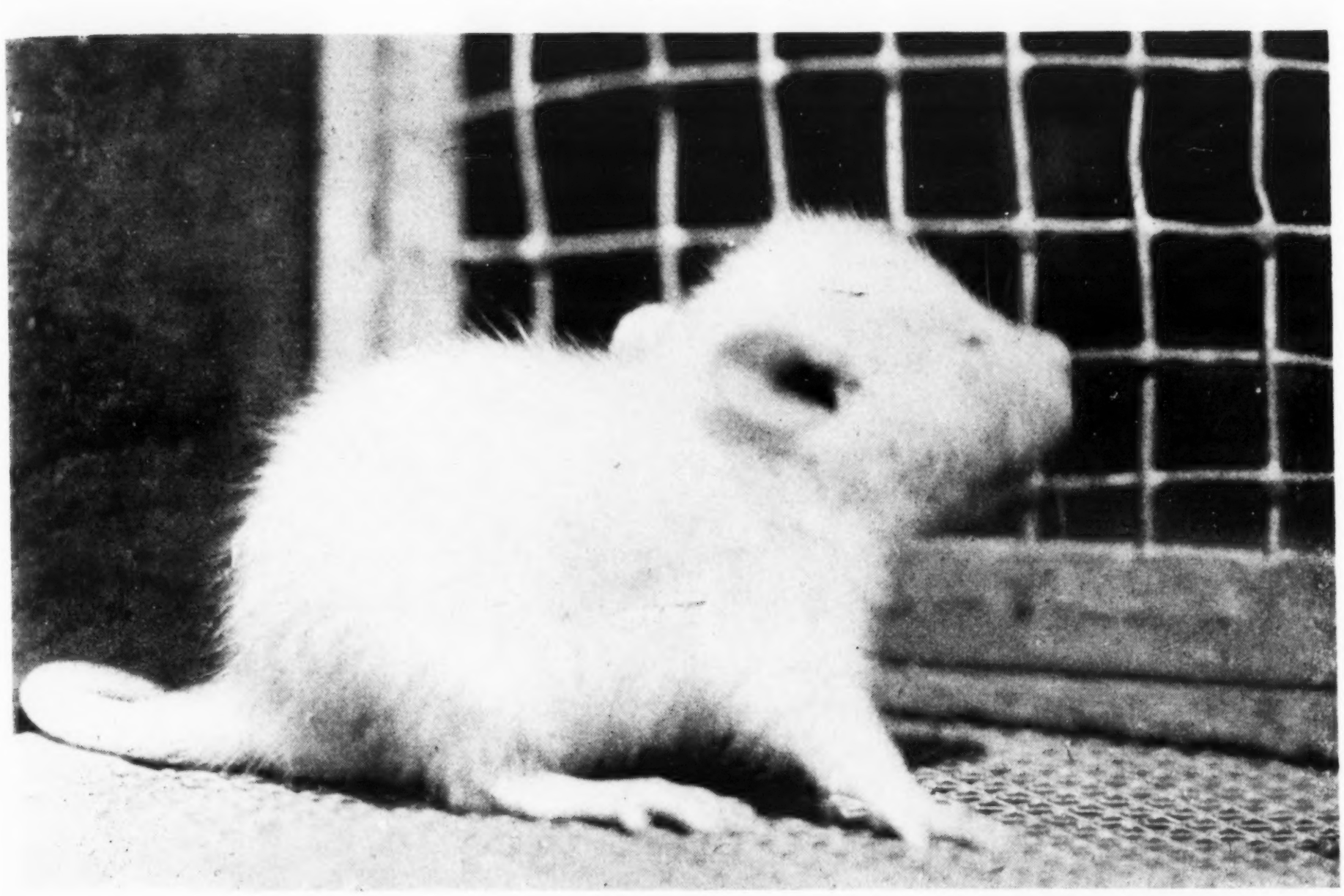
Wilhelm Fliess, a German physician, published several books in which he attempted to demonstrate that certain numerical relationships govern all organic life. Schleiper is his faithful pupil. Years of hard labor doubtless have gone into this book which from cover to cover is filled by a mystical play with figures. The data and the "methods" have no intrinsic value; the prolem is not to be sought with the material but with the author. In this respect the books of Fliess and Schlieper may offer problems of interest to the psychologist. and psychiatrist. These books demonstrate how far a preconceived idea may carry its author and how much can be done with a shallow conception of numerical relationships. Public interest oniy too easily yields to books of this kind which impress with their mathematical appearance suggesting exactness and with the simplicity of their conclusions which appeal to old superstitions. Whoever may be interested in Schlieper's book is urged to read as an antidote a recent publication by J. Aebly (Die Fliess'sche Periodenlehre im Lichte biologische und mathematischer Kritik. Published by Hippokrates-Verlag, Stuttgart—Leipzig—Zurich, 1928. Price $1.00) which gives a critical analysis of the methods employed by Fliess and Schlieper.

Walter Landauer.

"HIGH BROW" ALBINO RATS

HAROLD S. COLTON

University of Pennsylvania



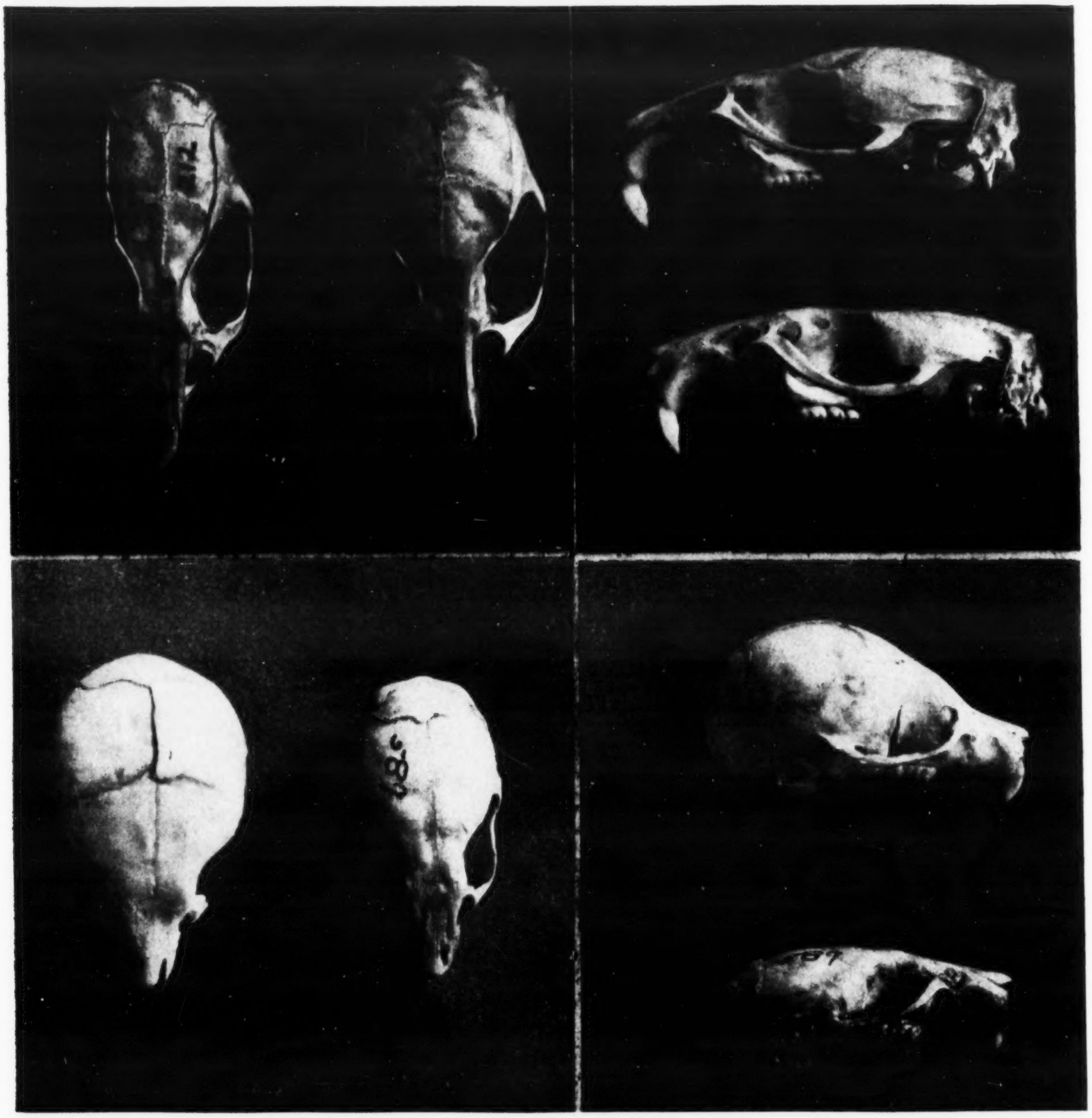
"MINERVA" TWENTY-SIX DAYS OLD

Figure 23

She is a cousin of "Socrates" (Figure 24). The fact that the "high-brows" are all related suggests a genetic cause. The scarcity of "high-brows" indicates no simple form of inheritance.

IN a litter of six white rats born March 20, 1926, three males showed a peculiar hydrocephalic condition. The frontal region of the cranium was quite bulbous, so that the profile of the rat's face was concave and not slightly convex as normal. (Figure 23). These rats we have called "high brow." This condition was not recognized at first and the first rat died at about twenty-one days and its body was not preserved. The second died at forty-four days. The skull was cleaned up and measured but when the skull was drying a mouse ran off with it so that it too was lost. The third rat lived for over a year and a half (508 days) and was killed so that the skull could be studied (Figure 24). This rat we called Socrates. Socrates was not an extreme "high brow" but his broad head and widespread eyes gave him an expression different from all the other rats in the colony. In the maze he did better than his normal relations but not enough trials were made to give significant results.

When Socrates was a year and a quarter old another litter was born in the colony which contained, among seven normal rats, a single female "high brow". We called her Minerva. Minerva lived to be twenty-eight days old. She might have lived to be older but a series of tragedies contributed to her end. She was placed in the sun to be photographed. After that she seemed sluggish. The next day she



"HIGH-BROW" AND NORMAL RAT SKULLS

Figure 24

Above—Skull of "High-Brow" rat "Socrates" 508 days old compared with that of a normal male rat of the same age. In the dorsal view "Socrates'" skull is on the right; in the side view it is above. *Below*—Skull of "Minerva," 28 days old compared with that of a normal female 31 days old. In each aspect the "High-Brow" skull is wider than the normal. "Minerva" is a much "higher brow" than "Socrates".

fell in the milk and became chilled. The following evening she died (Figure 23).

The body of Minerva was sent to Dr. H. H. Donaldson, who cleaned up the skull and reported her a case of hydrocephalus.

The skull of Minerva is a curious thing. (Figure 24). When compared with a normal skull of a rat of the

same sex and about the same age, the difference between the two is so wide that if the two skulls had been found as fossils they would be described as distinct species.

Relationship of the "Highbrows"

The colony of rats in which the "high brow" appeared was descended from one male and three female rats received from the Wistar Institute Experimental Colony strain on April 1, 1925. This strain, on the other hand, was derived from two individual rats some years before. Although brother-sister mating was not in general practice, we must conclude that the race is, by ordinary standards, highly inbred.

In tracing back the pedigrees of Minerva and Socrates, it was discovered that the ancestors came from two litters which had become mixed before the ears of the young rats had been marked; therefore, the exact relationships cannot be determined. We can say this much, however, Socrates and Minerva are either first cousins once removed, or second cousins once removed and that half their ancestors were common in the case of Socrates three generations back and in the case of Minerva four generations back; that is, they are both descended from the original male which was the Adam of the colony.

Socrates was mated with two of his sisters, and a son and daughter mated. None of his offspring nor his grandchildren or great-grandchildren showed the "high brow" character. Nor did any of the other 611 rats which have passed through the colony in the past three and one-half years.

As far as the work with this strain has progressed, it is not demonstrated that "high brow" is an inherited character. On the other hand, it is not proved that it is non-inherited. We can be certain that it is not caused by a simple Mendelian factor difference. If we assume multiple factors including lethals, the "high brow" condition might be hereditary. Be this as it may, the "high brow" rat is worth recording.

CORRESPONDENCE

The Synthetic Formation of Avena Sterilis

In a genetic study of interspecific crosses with oats at Davis, Calif., an interesting type of recombination of plant characters occurred. The crosses concerned were Coastblack × *Avena fatua*, and Fulghum × *A. fatua*. Coastblack and Fulghum are cultivated forms of *A. byzantina* with lemmas glabrous or nearly glabrous, and awns lacking, or the lower floret of the spikelets provided with a more or less weakly geniculate awn. The wild form used was typical *fatuna* with heavily haired lemmas and strongly geniculate awns.

In the F_2 generation, 45 plants in 408 of the Coastblack cross, and 4 plants in 478 of the Fulghum cross were typical *A. sterilis*, as that species is generally understood. The florets were disarticulate, and the lemmas of the two lower florets were provided with heavy hair and strongly geniculate awns. Seeds from these plants were sown and typical true-breeding families of *A. sterilis* were produced in the F_3.

Crossing in cultivated oats has been reported from widely separated localities. It is likely that it occurs also among the wild species of *Avena*. The possibility of recombinations in nature, with the formation of new varieties or forms of wild species is evident.

V. H. Florell,
U. S. Dept. Agriculture.

Photographed by J. M. Raeder

LITTERMATES WITH BRAIN HERNIAS

Figure 25

An inherited defect in the skull that is generally fatal, in this instance proving so an hour after birth.

AN INHERITED SKULL DEFECT IN SWINE

A Preliminary Report on the Inheritance of a Fronto-Parietal Skeletal Defect Involving the Meningocoele and Proencephalus Types of Cranioschisis in Swine

JULIUS E. NORDBY

*Agricultural Experiment Station University of Idaho**

DEFECTIVE anatomical and physiological development during embryonic life gives rise to various types of anomalies in our domestic animals. A large number of these are of the monster types which have not been definitely associated with hereditary factors, and it is likely that the causes underlying their origin may be explained more satisfactorily on the basis of aberrant embryologic development. Monster types of this kind are comparatively rare in their occurrence among our domestic animals and are of scientific rather than of practical interest.

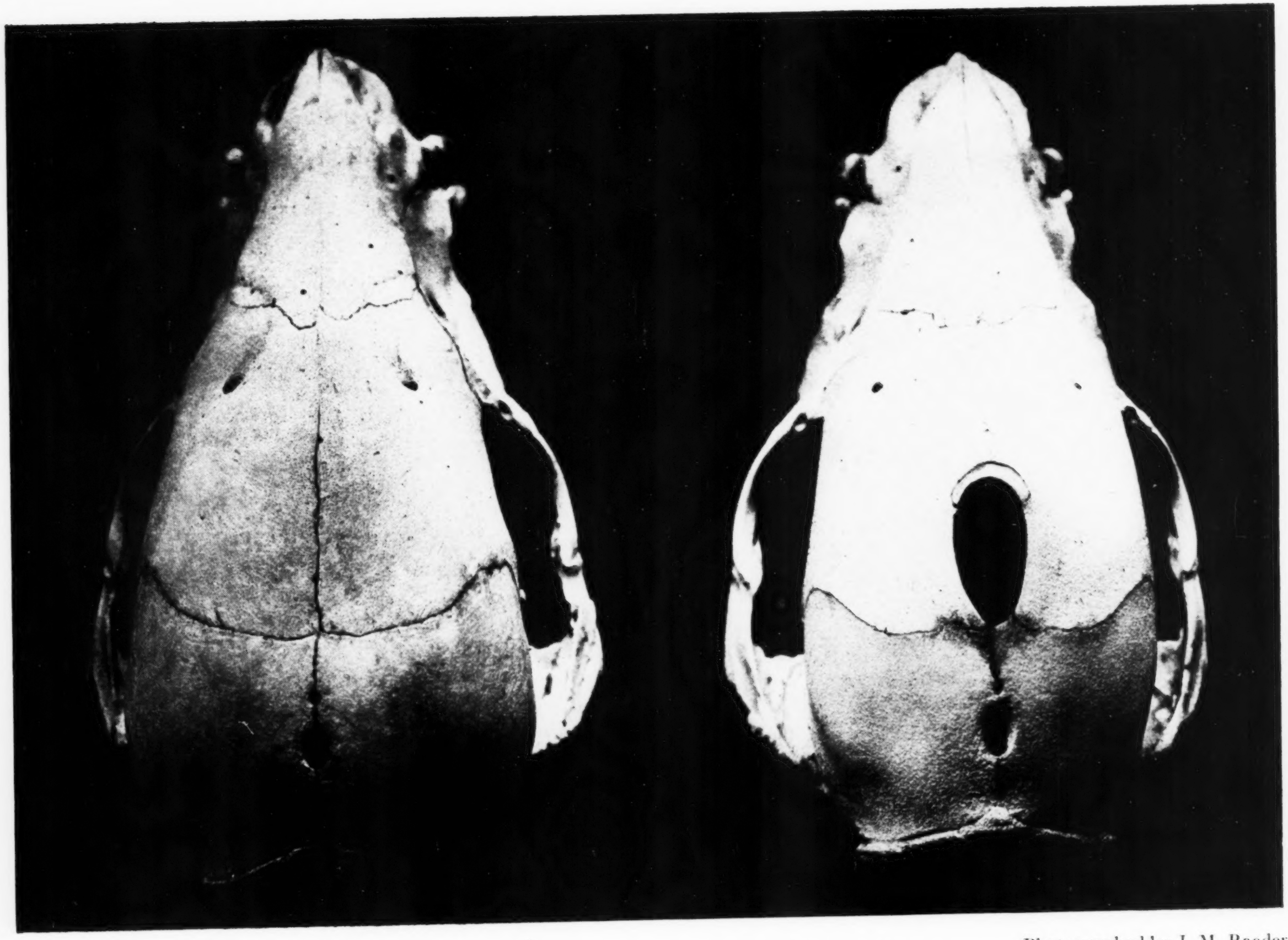
It has been found, however, that many types of defects both anatomical and physiological are hereditary. These vary in their influence from the lethal and semi-lethal types to the less significant defects effecting slight changes in the external anatomical pattern, a large number of which are reported in the literature on this subject.

The defect illustrated in the accompanying photographs is of the meningocoele and proencephalus types which represent incomplete development of the neural tube involving the bony investment surrounding the brain and especially the frontal and parietal bones. During embryonic life the neural groove has failed to close, thus allowing the brain membranes and fluid, and in some cases brain tissue, to protrude from the fissure. The imperfections vary from epithelial defects in the fronto-parietal region, that are suggestive of "sutural" alopecia described by Hyde[2] inasmuch as the skin adheres to the deeper parts and the growth of hair is indifferent, to typical meningocoeles involving the protrusion of the dura mater and arachanoid, and consequently the brain fluid, and the proencephalus type where the pia mater also has pushed out allowing brain tissue to escape through the frontal fissure. The accompanying cuts show the nature of the defect as a brain hernia on the front part of the skull, and with skull openings in the same defective pigs. The defect is reminiscent of the "Catlin Marks" or "eyes in the back of the head" reported in this Journal by Goldsmith[1]. It is apparently the same defect that Williams[3] has reported as "Hernia Cerebri".

This defect has been under observation in five purebred herds during a period of four years. More than 200 subjects have been studied. Very close inbreeding has been done with affected subjects. Sufficient data are available to permit the defect to be recognized as hereditary, and, in most cases it is lethal inasmuch as only very few affected pigs survive. The pigs that do live are very susceptible to epileptic fits and some die from sunstroke.

Extreme variations occur in the brain hernia on the forehead. Some pigs have one and some have two of these defective developments. In general, the size depends upon the variations in the opening of the skull. Exceptions to this occur when during prenatal life the skull defect has almost closed, preventing the protruded tissues from pushing back into the brain cav-

*Published as a preliminary report with approval of the Director as paper No. 58 of the Idaho Experiment Station.



Photographed by J. M. Raeder

VARIATION IN SIZE OF SKULL OPENINGS

Figure 26

Skulls of two pigs shown in Figure 27. There is no particular relation between the size of the openings and

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Photographed by J. M. Raeder

TUMOR-LIKE GROWTHS DUE TO SKULL DEFECTS

Figure 27

Two defective littermates that were farrowed alive but died within an hour.

ity. A number of such cases are on record. Post-natal ossification of the skull bones occurs in affected specimens that survive. The possibility of an affected subject surviving does not seem to be entirely in proportion to the size of the fissure inasmuch as some of the specimens with exceedingly large exterior developments have survived, which, when examined for skull defects have revealed very large openings. And again some pigs have been farrowed dead which have had the slightest developments both in the exterior and interior manifestations of the defect.

Some mummified specimens have been farrowed at term with normal litter-mates. The variations occurring in their development seem to indicate death at different stages of pre-natal life. Some litters that have been produced, by the close mating of subjects known to carry the heritage necessary for producing the defect, have been small, varying in size from one-half to two-thirds the usual number, in which all of the pigs farrowed were apparently physically normal. This probably indicates lethal disturbances and resorbtion in early pre-natal life. It appears inadvisable to draw definite conclusions, with respect to the exact nature of the inheritance, in view of

the extreme variations which occur. The problem is being developed to include embryological consideration which should in time reveal definite information with respect to a fuller appreciation of the hereditary behavior as well as affording a more comprehensive understanding of its lethal nature.

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Celebration of the Twenty-Fifth Anniversary of the Founding of Carnegie Institution of Washington

ON Friday, May 31, at Cold Spring Harbor, Long Island, the Department of Genetics of Carnegie Institution of Washington will receive invited guests in celebration of the twenty-fifth anniversary of the organization of the Department and of the beginning of the active work of research for which Carnegie Institution was founded.

The Exhibition

A program of exercises has been arranged which includes brief addresses by members of the Board of Trustees of Carnegie Institution, by Dr. E. G. Conklin, Professor of Biology, Princeton University, and by Dr. John C. Merriam, President of Carnegie Institution of Washington.

By way of illustrating the current work of investigators in the field of genetics and related fields, the staff has organized a number of exhibits. These exhibits are designed to show what has been accomplished to answer the question: What is it that makes differences and likenesses among living things?

On Saturday and Sunday, June 1 and 2, between the hours of 10 a. m. and 1 p. m., and 3 p. m. and 6 p. m., the exhibition will be open to the public.

The Work in Genetics

Genetics is the phase of the study of life that deals with differences and likenesses which appear in living things. Throughout the plant and animal kingdoms, offspring tend to resemble parents and ancestors but they never exactly resemble them.

As the relationship becomes more and more distant, the differences increase. These likenesses and differences are partly due to environment, but primarily they are due to the hereditary material which has been passed down from parent to offspring since life on earth began its continuous career. Genetics seeks to explain the processes by which the vastly different sorts of living things have developed and to formulate the laws which govern.

For twenty-five years the Genetics staff of Carnegie Institution has been at work upon various details of this vast problem. By studying the hereditary material itself in the laboratory with stains and microscope and camera; by inducing a multitude of matings among plants, insects, and vertebrates, and studying the offspring; by making statistical studies of racing capacity in horses; and by collecting the individual and family histories of thousands of persons and analyzing them from the standpoint of hereditary traits—by these and other methods have the members of the staff sought with gratifying success to cooperate with scientists elsewhere in penetrating the secret of inheritance and of variation.

Investigators to Explain Exhibits

Visitors will be shown the plant and equipment which Carnegie Institution of Washington has developed at Cold Spring Harbor. They will enter the greenhouses, the insectaries, the animal houses, the laboratories, and be told by the investigators about the problems upon which each is at work and how the results are being fitted together, mosaic-like, into the picture which is being drawn of how life functions in the cellular world.

The plants and animals themselves, explained by charts, drawings, models, photographs, lantern slides, moving pictures, microscopes, and descriptive talks, will serve to open the windows upon this thrilling drama wide enough for the layman to see and appreciate somewhat of its interest and significance.

SOME PRODIGIES

PAUL POPENOE

Pasadena, California

A NINE-YEAR-OLD boy from Vermont stood before the Duke of Cambridge.

"Give the number of seconds since the beginning of the Christian era, 1813 years 7 months and 27 days," he was told.

The child thought a moment. "57,234,384,000", he replied.

Zerah Colburn was one of the most perfect specimens of child prodigy along arithmetical lines. His facility was noticed when he was about six years old and was playing on the floor one day. His father heard him repeat to himself what sounded like parts of the multiplication table. He had not been taught this, and presumably had picked up the information from other children.

The father was interested, and began to ask questions. Soon he said, "What are 13 times 97", and instantly came back the correct answer, 1261.

The child later extracted square and cube roots mentally without hesitation and, being asked by the Duke of Cambridge to raise the number 8 to the 16th power, did so with only a minute's thought, although the answer ran into hundreds of trillions. At this time he was not an educated boy—he had learned to read and write, and that is about all. But he is said to have been a wide and interested reader.

He was taken to Europe and exhibited. Napoleon, who had just then returned from Elba, sent him to the Lyceum Napoleon in Paris to continue his education. He was afterward schooled in London, became a teacher and a Methodist preacher, and ended as professor of languages at the University of Vermont, giving instruction in Greek, Latin, French and Spanish. His mental powers declined rapidly and he died at the age of 38, a man of very ordinary intellectual capacity.

Here is a case that presents some interesting problems (one of them, incidentally, being his inheritance through four generations of six digits on each hand and foot). As a child Zerah was considered dull, definitely inferior to his five older brothers and sisters. If tradition (supplemented by his highly conceited autobiography) is to be trusted, he blazed out like a comet, and then declined with almost equal speed.

Can his career he attributed to the influence of his surroundings? Evidently not. He was certainly no hothouse product, no forced prodigy as have been some other "child phenomena". On the other hand, is it possible that such a peculiarity is inborn; if so, why did it disappear?

Lightning Calculators

It is impossible to answer these questions definitely. Some light on the general problem has been thrown by the study of other lightning calculators.

One of these, who has appeared on the vaudeville stage for many years, and who is designated in the examination[1] as K, claimed to have a ready command of the following assortment of facts:

1. The population, by the 1920 census, of every town and city over 5,000 in the United States. (He had previously learned the population of all towns over 2,000 by the 1910 census, but this obsolete information he was now "trying to forget.")

2. The names, number of rooms, and location of about 2,000 leading hotels in the United States.

3. The county seats of all counties in the United States.

4. The population of 1800 leading foreign cities.

5. The distances of all cities in the United States from New York and from Chicago, and also the distance from each city or town to the largest city in its state.

6. Statistics concerning 3,000 mountains and rivers.

7. The dates and essential facts connected with over 2,000 leading inventions and discoveries.

Tests showed that his claims were substantially correct, and that he also had a vast "unclassified" stock of facts from geography and history. He had learned his associations both ways; he would give the population of a city if its name was called, and he also made such a record as the following, when the mere numbers were called:

Q. 74,684.
A. San Diego, Calif.
Q. 83,252.
A. Savannah, Ga.
Q. 8,481.
A. Coshocton, Ohio.

The striking thing in K's equipment is not the total number of facts, which is doubtless exceeded by many well-informed persons, but the classification of them, and the fact that they presented no natural associations, and thereby taxed his memory the more. He had gone over his facts so often that he could break them up in many peculiar ways, and the performance was well adapted to "astonish the natives" on a vaudeville circuit.

One of the standard intelligence tests measures memory span, that is, the number of digits that can be recalled after a short interval. In general, the average child can do, at the ages stated, the following:

Age	4	5	6	7	8	9	10	11	12	13	14	15	16	17
No. of digits that can be repeated	4	4	5	5	5	6	6	6	6	7	7	7	7	7

K was given the number 4836179621, which he studied for 35 seconds, and was able to reproduce correctly after a four-hour interval. Few adults could accomplish this. Does it show a particular gift of memory?

Apparently not. K described his method as follows:

"When I saw this number, I read it as 4,836,179,621. I remembered 4 because of the 4th of July. 836 I just had to memorize, without any help, but if I were doing it again it would probably occur to me that 836 was the Chinese population of the state of Texas in 1910, and then I wouldn't forget it. 179 is easy to remember because it is the number of miles from New York to Harrisburg, and 621 is the number of a house I know of in Denver."

By these linkages he was able to reduce the number of units from 10 to 4. Probably there is no other way of remembering large figures. Abundant tests have shown that the memory span is fixed and constant for each individual, and that it is not improved with practice. The only way it can be exceeded is by the use of some such device as that of K.

Astonishing Records

Men of science sometimes enjoy demonstrating such systems, the best known in the United States being that of the psychologist, Arthur S. Otis. Some of the records would be incredible if not well attested. A Norwegian philologist, Paula Bergh, learned 408 figures in 104 minutes, thereby taking the record which was previously held by Diamondi, a "professional" studied by Alfred Binet. His limit was about 200 figures, which he learned in 75 minutes, and reproduced correctly in writing.

Dr. Bergh's record, however, was quickly broken by G. Rückle, a German mathematician, who learned a series of 504 figures in 40 minutes. All of these learned visually. Dr. Rückle groups the figures in associations which he can see mentally. Dr. Bergh has not, as Dr. Rückle has, a particular fondness for figures; she is not mathematically inclined, nor even good at calculation.

Her habits of mind being more literary, she individualizes the figures as persons, places, or objects, and then builds in her mind a whole landscape. By looking at this, she can describe it, thereby reading off the figures.

It is unfortunate that a scientific description is not available of the working of the mind in some of the historical families celebrated for good memories, as that of the classical scholar, Richard Porson. Marcus Annaeus Seneca could repeat 2,000 words in the order in which he heard them, if historians are to be trusted; his son Lucius was also, though less highly, gifted in this respect. When 350 words were read to Paula Bergh, with 8 seconds allowed for the study of each, she repeated the whole series at once with only 11 per cent failures, and even after a year, in which she had given it no further thought, she was still able to recall one-third of the words.[2]

From such studies as these, it is inferred that there is no special "memory for figures" nor any other specific capacity of that sort; the achievement requires only the capacities that are used in other kinds of learning; but quite unusual amounts of some of them such as concentration and lack of fatigability. On the other hand, the visual fantasy that seems to make the most astonishing achievements possible is possessed by few, and can hardly be cultivated by those who do not possess it. It recalls the families discovered by Francis Galton, members of which always thought of figures in definite patterns or frameworks, which were sometimes represented to the mind's eye in colors. He believed that this peculiarity was inherited, as in several instances the offspring did not know that the parent also possessed it; but the whole subject needs to be restudied to verify this conclusion.[3]

K. is not, broadly speaking, an intelligent man. He was 38 years old at the time of the examination, but tested 11 years and 10 months mentally, which gives him an IQ of 74 and puts him among the "borderline" group, just above the moron, but not definitely normal, not even dull normal. In general tests of logical memory he was not even as good as the average normal.

The Part of Compensation

How, then, is his "talent" for memorizing to be explained? Is it a case where an individual with few gifts in general is compensated by a particular gift in one direction, as Ralph Waldo Emerson would have opined? The examiner in this case believes not. He traces K's early history, showing that he is physically defective, did not adjust himself well in school because of his retarded mentality, his markedly effeminate manner, and a speech impediment. He tended, therefore, to isolate himself from the world about him and to live in a world of fantasy, in which he attempted to compensate for his inferiority in general by believing that at least he had a great superiority over other children in one respect: he would be a "memory artist".

This explanation holds, in short, that the compensation was not provided by nature, but was one worked up by the subject for himself. This is the only kind of compensation of which anything is known scientifically.

But why, one might ask, did K pick out this particular field in which to compensate for his inferiority complex? He might have done it in any one of a thousand other directions. Most people are compensating or overcompensating to themselves for some real or imagined inferiority*, and few end as "memory artists". Is it not likely that his compensation took

*The inferiority complex is to be looked upon as a normal part of the human mentality—the reaction of an organism that is never perfect, toward the overwhelming forces of nature and mankind against which it must battle continually. Investigation shows that it is more pronounced among women than among men. This is probably associated with a neurotic constitution, introversion, and social limitations.

this form because nature had given him a start in this direction? This supposition is made the more plausible by the admission that "K received much encouragement from his mother, who regarded herself as possessing unusual memory abilities, and liked to think of her son as following in her footsteps."

The same sort of explanation must be applied to other cases which have been interpreted too superficially, merely as the product of mental mechanisms. These mental mechanisms must have a physical basis to work on, and this physical basis is provided by the peculiarities of the subject's inherited constitution.

There are many cases on record of memorizing ability associated with mental defect. The opinion has often been expressed that "phenomenal" memory may be associated with idiocy. Some of these cases have been examined carefully in recent years.

For instance[4], "Mark, a 19-year-old boy at Letchworth Village, has a remarkable memory for and recalls with facility anything that has been taught him—dates, names, places, or events. Geographical names of obscure and little-known places, dates of significant or insignificant historical events, names of important or unimportant persons, if once known are never forgotten." He is a characteristic mental defective, but not of low-grade.

An Imbecile's Achievement

Eugene Hoskins[5], a pure black in Mississippi, has, on the contrary, a mental age of only eight. His auditory memory span is relatively short—he failed on five digits, which a normal six-year-old should repeat. By sheer effort, however, Eugene has committed to memory a large array of facts relating to dates, places, and particularly locomotive numbers. In the years 1921-4, given the month, day, and year, he will at once name the day of the week; or if given the year and month, and asked what day of the month was the second Tuesday, or the fourth Friday, he never fails. At the time of the examination he was extending this ability to the year 1925.

In this case it is clear that the information was acquired merely by hard work, and the explanation offered is that he had not enough sense to know any better. If he had been normal he would not have been willing to spend all his effort on acquiring useless information.

This explanation is acceptable so far as it goes, but again it seems to fall short. Such cases as that of Mark, and many others in the older literature, indicate that there may be inherited differences in memorizing ability, and that these are inherited more or less independently of general intelligence. Such a supposition does not involve the supposed Law of Compensation lauded by philosophers; it merely involves the fact, well attested in all studies of heredity, that to a large degree different traits may be inherited independently. Correlation exists, but it is often not a high correlation. As a fact, tests have demonstrated that memory has little or no correlation either with general intelligence or with school standing.[6]

How is it, then, with Zerah Colburn, the boy prodigy? He performed, untaught, feats that are quite impossible for the brightest boy. It is open to question whether any bright boy could be taught to extract the cube root of 268,336,125 mentally, or to give the square root of 998,001 in four seconds, as Zerah did.

If it is true that he was considered dull as an infant, it is conceivable that he worked up his ability as a calculator, in an effort to compensate for this reputation, and thus to satisfy self-esteem, which was large. It is conceivable that he was gifted with a memory much above the ordinary, which aided him. It is conceivable that he really was extremely bright, and that his early decline was due to some mental disease.

Such speculations do not solve the problem, which at present must be left unsolved. When all the facts are considered, however, it is difficult to believe that any explanation is satisfactory, in the case of prodigies, which fails to take account of real, inherited differences, in such mental functions as memory and calculating ability.

In other words, such performances require not only a "system", but also a "gift".

The Traditional Explanation

That the gift comes before the system is indicated by the traditional origin of the system, which the ancients ascribed to Simonides of Cos (556-468 B. C.), who was not only a classical poet of repute, but perhaps the first poet to commercialize his art. He was the man to whom every wealthy parvenu turned for the contribution of a suitable epitaph, or a couplet to celebrate success at the Olympic games. In his youth (Marcus Tullius Cicero tells the tale in his essay *De Oratore*) Simonides, who was attending a banquet, went out, whereupon the roof fell, killing the whole company. When the debris was cleared away the bodies were found to be crushed beyond recognition; Simonides identified them all, however, because he remembered their positions. This called his attention to the fact that order or arrangement is the greatest aid to memory. The most expensive correspondence course in memory training, at the present day, has gone little farther than the discovery of Simonides.

Various kinds of complementary evidence enforce the conclusion that mathematical talent (which itself embraces a large number of diverse capacities, not yet fully analyzed, about whose independent inheritance little or nothing is known), is dependent primarily on inheritance.

1. It runs in families, as that of the Bernouillis, which produced eight outstanding mathematicians in three generations.

Similarly, lack of mathematical ability may run in families. In a study[7] of a large family of defectives and delinquents in Pennsylvania, a strain was found in which there seemed to be an inherited lack of the sense of quantity and number. When Aaron Rufer went to work in the morning he had to measure out the meat and potatoes which his wife was to prepare for dinner. If he left it to her, there was no telling how much she would cook. In one line this defect has persisted for five generations; in others, marriage with normal persons has brought an improvement.

2. Direct measurement of the degrees of difference between parent and offspring shows that they behave as if due to heredity[8], and there is also segregation—not all the members of a family are gifted alike. One of the greatest calculators of recent times was Jacques Inaudi. His brothers became envious of his fame and tried to set up in the same business themselves, but without the slightest success—it was not in them[9]. Jacques was an uneducated boy—he did not even learn to read and write until he was grown. His methods seem to have been comparable to those of K.

3. It appears at an early age, as in Zerah Colburn's case. Probably most of the mathematical prodigies have not been freaks, but men who later became distinguished in other lines—among them James Watt, one of the inventors of the steam engine; William Herschel, the astronomer; D. F. Arago, the astronomer; P. S. Laplace, the astronomer; Isaac Newton, who had invented the differential calculus before he was 24; A. M. Ampère, the physicist, and men who devoted their lives to mathematics, such as K. F. Gauss, L. Euler, Th. Joung, and George Bidder.

Segregation in Heredity

4. It behaves independently in transmission. It may appear with almost

any other type of talent; it may be lacking with almost any other type of talent. It is generally believed to be rare in association with literary talent and artistic talent except musical, but commoner with musical talent. A study on this point, however,[10] did not reveal that musically gifted people are any more mathematical than the rest of their relatives. Most commonly, it appears in men and women who possess a high degree of general intelligence; but the examples cited in this chapter show that some forms of it, not depending so much on mathematical reasoning as on memory, may be found in persons of relatively low intelligence.

5. It comes out in spite of discouragement. Several of the Bernouillis were educated for other careers, but the urge of mathematics was too strong for them, and they gave up their professions in order to devote themselves to their specialty. Karl Pearson has also told graphically how, after he had become a lawyer, the necessity, so to speak, to be a mathematician caused him to break entirely with his surroundings.

6. It is little influenced by training. This has been shown not only by a wide range of special tests in psychological laboratories, but by the actual experiences of school children. In a study of California pupils at 8, 11, and 14 years of age, it was found that arithmetical ability changed less than almost any other ability tested (spelling ability was the most nearly comparable in this respect*), and that approximately 97 per cent of the adult differences in this capacity could be ascribed to original nature, which the years of training had modified to the extent of only 3 per cent.[3] Arithmetical computation was also extraordinarily independent of training, spelling again being second.

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*Spelling ability seems to be as much determined by heredity as is any ordinary mental trait, the correlation between children of the same parents being .50. Little or no relation has been found to exist between spelling ability and various methods of instruction or school surroundings, or even foreign parentage.[11] Above a given minimum—say, among college students—spelling ability is not closely associated with general intelligence.[12]